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ABSTRACT

This methods book is divided into 13 parts. The first 12 parts (each beginning with a list of performance objectives) focus on: understanding the nature of science and technology; reasons for teaching science to children; a short history of elementary science methods in the United States; the products of science; the processes of science; scientific attitudes; modern science programs; science textbooks; preparing instructional materials; the incidental science experience (a casual or undesigned happening related to science instruction in the classroom); understanding and teaching environmental education in the elementary grades; and teaching science to children with special needs. The last part consists of a list in which traditional and modern science methods are compared and a list of conditions necessary for an effective elementary school science program. Assignments related to concepts, supplementary readings, writing and analyzing performance objectives, preparing for instruction, and textbook appraisal are included in appendices. Lists of resource materials and information on metric measurement are also included in other appendices. (JN)

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SCIENCE TEACHING METHODS FOR THE ELEMENTARY SCHOOL

A Worktext

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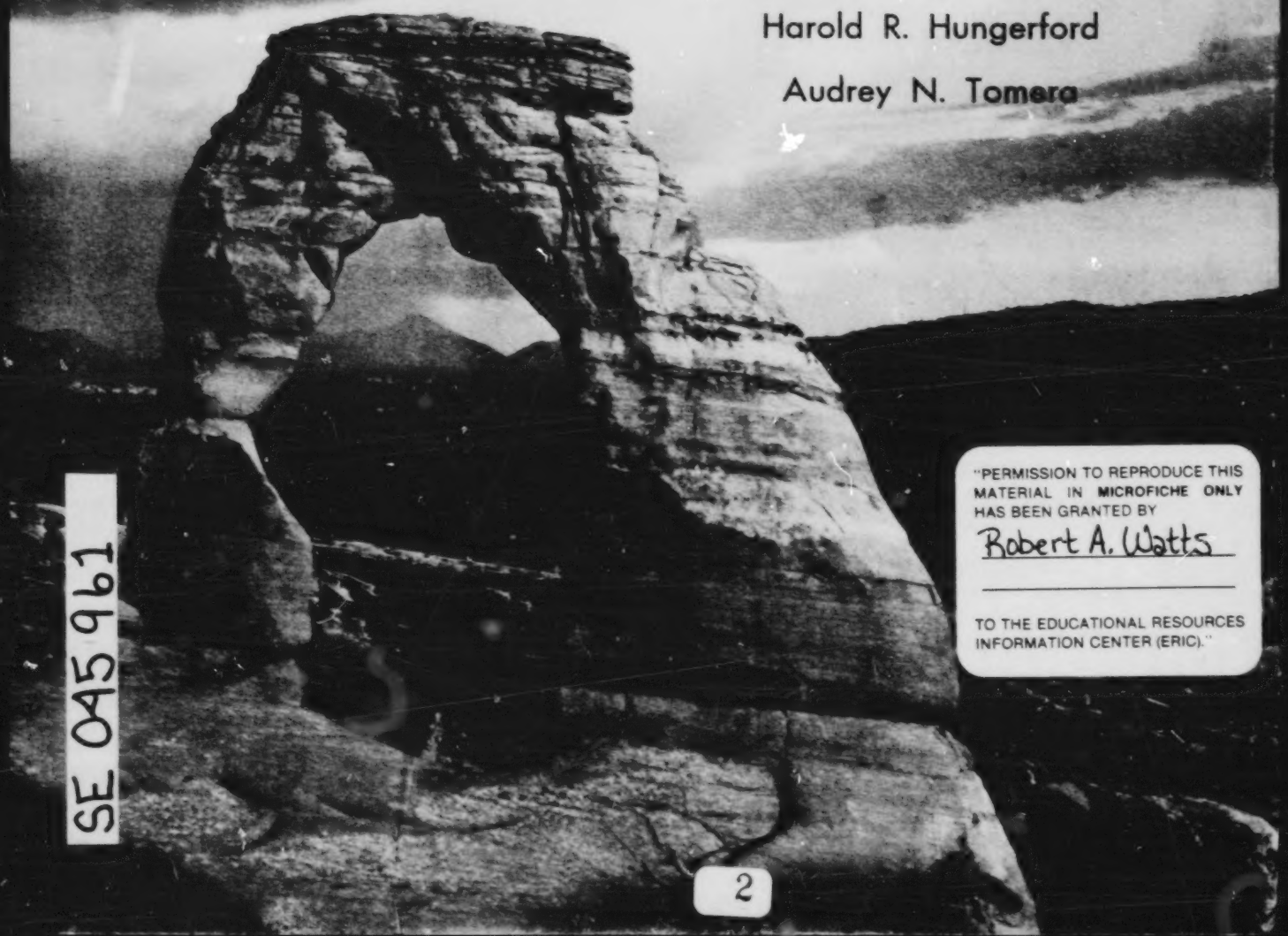

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A Worktext

Harold R. Hungerford

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Department of Curriculum, Instruction and Media
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The contributions of a great number of individuals over a period of many years have helped make this book what it is. The reactions of the methods students (who have suffered through our efforts to design for them the best, well-rounded methods course possible) have done much to improve the readings and activities included in this worktest.

As the original handouts leaped from both ditto and mimeograph machines, a good many people were willing to give editorial opinions concerning their contents. Included would be Ron and Linda Gardella, Ralph Litherland, Roger Robinson, David Miles, Gary Harvey, Morris Lamb and Kevin Swick. Also involved in subsequent editorial work were Peter Rubba, Donna Childers, Pat Patinella, Archie Sia, R. J. Wilson, Trudi Volk and Jody Hines, all of whom contributed a great deal to the final product. In addition, the authors would like to express their thanks to the Commission on Science Education of the AAAS for its willingness to permit the writers to quote directly materials from the SAPA program and to the National Science Teachers Association for their permission to use their science materials address list.

And then there were those who, believing in the authors, willingly taught the trial editions of what is found in this worktext. Bill Bluhm, Ron Gardella, Jody Hines, Bahman Saghatchian, Archie Sia, Henry Walding, R. J. Wilson, and Trudi Volk draw praise for their dynamic, compassionate, and competent teaching!

A publishing deadline always seems a bit ethereal and traumatic at best. Meeting the deadline of this worktext was not totally a function of the authors. A tremendous amount of time was devoted to manuscript preparation and art work by Bill Bluhm, Henry Frazier, Dan Sivek, and Diana Zoeller. The authors could not have met the book's deadline without their contributions and selfless support. In addition, R. Ben Peyton and Rick Wilke are responsible for a great deal of productive creativity with respect to the environmental education section of this publication.

Harold R. Hungerford

Audrey N. Tomera

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PART I

On Understanding Science and Technology

Performance Objectives

Subsequent to your interaction with Part I you will be expected to be able to. . .

1. . . . explain why science was created by man and why it must be considered as a product of man's intellect.

2. . . . define, or identify an accurate definition of empiricism.

3. . . . defend the position that science per se has but one ethic - the ethic of of empiricism.

4. . . . describe the characteristic(s) of scientific truth that separate science from other kinds of truth bases, e.g., authority, faith, religious dogma.

5. . . . define, or identify accurate definitions of process and product as associated with science.

6. . . . describe and/or diagram the relationship that exists between process and product and explain why this relationship is considered to be a cyclical one.

7. . . . differentiate between science and technology.

8. . . . based upon your answer to Objective 7 above, identify two (2) misconceptions that humans have concerning science and technology.

9. . . . defend the idea that science and technology should be separated conceptually in the minds of both teachers and students.

> . . . every citizen (must) have a basic and functional understanding of the products of science - the concepts, the principles and the facts; and be able to understand and use the process of science - the modes of thought, the attitudes of mind, the tactics and strategy, and the appreciations,. . . . This goal can be achieved through the school . . . It must have the support of every citizen in every local community. It will require a concerted and organized effort, but these costs are low when weighted against the realization that this kind of education in science may be basic to our survival.
>
> Ellsworth S. Obourn - 1961

> Science in itself furnishes none of the ends of action; in so far as the knowledge of the scientist is concerned, it is immaterial whether what we know of high explosives is used to build a great reservoir to make the desert blossom as the rose, or to construct giant shells to snuff out the lives of an entire city. As a man the scientist may, nay, must, make some preference; but the grounds for that preference are not to be found in physics.
>
> Columbia Associates in Philosophy - 1923

Over the centuries, philosophers and common men alike have struggled in an attempt to perceive man's true role in the universe as well as his destiny. Unfortunately, we look at man and find him almost unbearably complex and mostly uninterpreted. Man, unlike the other creatures to whom he is related anatomically and physiologically, is blessed - or burdened perhaps - with a highly developed, curious mind. The complexity of this organ does not permit him to escape the inexorable ties to the environment which he shares with other creatures but it does permit him what many would call the rationality and responsibility of being human. This, of course, refers to man's ability to look as his environment, interpret it, and solve those solvable problems with which he chooses to cope.

This rational quality of man separates him from the rest of the living creatures on the earth. It allows him to develop the thing called culture and all of the blessings and problems that culture brings with it. One of the products of man's mind, and an integral part of his culture, is science!

The writers who have dealt with the question, "What is science?" are many. If there exist numerous responses to this question, then why do we deal with it here? The answer is simple. Those who propose to guide students' minds toward accurate concepts concerning science and scientists, (and this includes you) must have clear and thorough concepts themselves before they can adequately broach the topic in the classroom. Indeed, the lack of accurate concepts of science and scientists may well provide a partial answer to help explain a lack of understanding concerning what science education should encompass. It seems to the writers that prime prerequisites for competent science instruction (and learning) are workable and accurate concepts of science and the scientist.

What Is Science?

This question, given to any large population of rational human beings, produces a wide array of responses. Perhaps the most common and least meaningful definition is to say that <u>science</u> is <u>inquiry</u>. This pleases almost everyone but it fails to communicate what science is because there is usually a wide spectrum of interpretation regarding "inquiry".

Man is, to a great extent, a curious animal. One has only to observe children discovering new things or listen to the gossip in the beauty shop to find evidence of this. Similarly, man's tremendous intellect finds an uneasy peace

when something exists within his limits of perception and remains uninterpreted. His almost insatiable drive to "understand" in order to satisfy his curiosity has caused the creation of the enterprise called science.

Man searches for truth in many dimensions. However, one kind of truth is basic to those who are called scientists. This truth is called empiricism. In essence this form of truth (empiricism) is based on the belief that only those things which man can experience directly or indirectly through his senses have reality. Empiricism differs from a reality based on faith or a belief in authority. It is this quality that separates science from authority-based truth of dogma, e.g., religious faith.

Sensory reality or experimental truth - often called empiricism - brings into being that dimension of man's culture called science! (Note: Empiricism is often referred to as the generation of knowledge about something by experimental means or direct observation. It involves data produced through scientific process - data which are replicable by other members of the scientific community). Stated in a simpler manner, we might say that science is man's way of investigating the objects and events of the total environment in a manner that provides empirical knowledge of these objects and events.

Science differs from metaphysical or ethical knowledge in that scientific knowledge is empirically truthful or at least supported by empirical evidence. There is little room for faith alone or intuition in science. Regardless of the value of a scientist's intuitive judgment, his intuition must eventually be replaced by an empirical construct or his investigation is worthless. Man has demanded this of science and, as a consequence, science has little else to offer! Science is a human enterprise constructed on one ethic and one alone - that of empiricism.

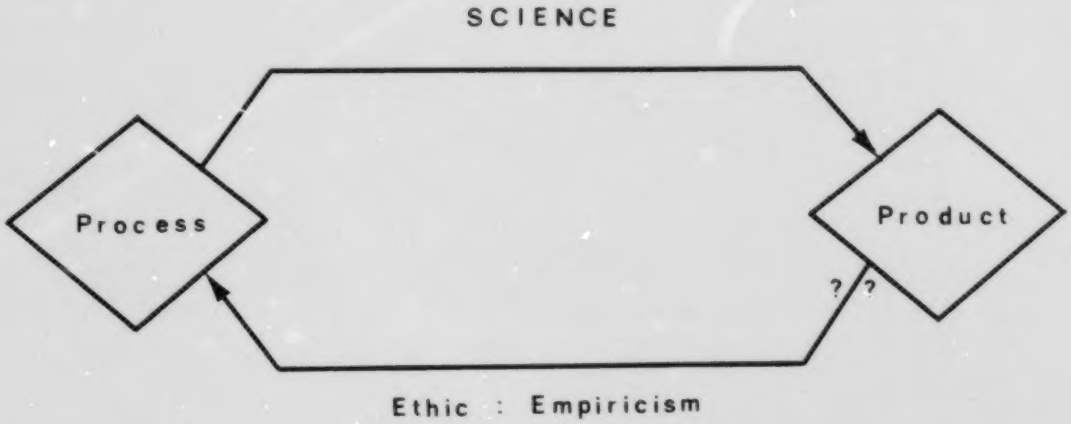
This ethic has often caused problems for the scientific enterprise because science ends with the creation of empirical data. Science assumes no other moral or ethical responsibility. It is what man himself does with empirical data that leads to moral dilemmas. This is one of the most difficult concepts for students to understand . . . that moral judgments are not in the realm of the working scientists - only empirical judgments count when science is being conducted.

The Process and Product of Science

The means by which science investigates the universe are many. The old shopworn slogan for the tool of science is the "scientific method". This is a grave error. To limit science to one, highly-structured investigation strategy is to absurdly oversimplify the entire endeavor. Science is a wide array of intellectual scientific processes whereby man can generate or discover data. The simplest, yet one of the most productive, is observation. The most complex is experimentation. Other scientific processes used are comparison, classification, inferring, controlling variables, hypothesizing, measuring and so on. Although all intellectual science processes are not mentioned here, it is hoped that the reader will realize that the processes are many and varied - not one in nature. They are a reservoir of mental skills that can be called on by scientists when needed. These intellectual skills constitute the process aspect of science - the means of empiricism - the means by which men generate knowledge concerning the environment about them.

As lucid as the notion of process may appear to the reader it is only part of the story of science. Process may be the means but what of the end? The end, of course, is knowledge or product. Product is, in science, the purpose of process. Without the vast reservoir of knowledge science has contributed, process would be totally inconclusive and the enterprise of science a moot issue.

Thus we can see that science is a combination of two things - process and product. The relationship between the two, however, is seldom directional. Process breeds product but with new knowledge usually comes more questions that impose new demands on process. Similarly, scientific product is always amenable to modification as the result of continuing scientific inquiry. It is unlikely that the cyclical nature or process and product would ever end in a healthy cultural setting.



And What Of Technology?

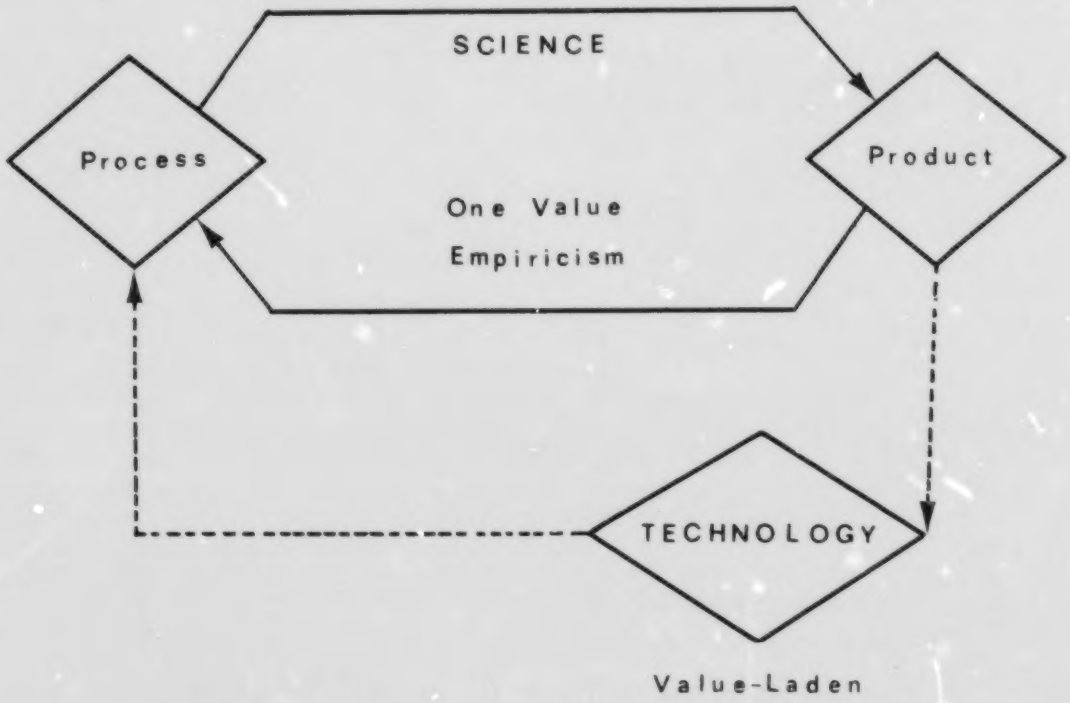
The distinction between science and technology is an important dichotomy with several implications for education. How man uses the knowledge of science (use = technology) constitutes a distinct and separate cultural component from science per se.

Technology is simply "applied science". In our discussion of technology we will arbitrarily refer to the term as meaning any socio-cultural application of scientific product. Fleming's scientific discovery of penicillin, when used to treat an infected throat or gonorrhea, becomes a medical-technological application. It is no longer scientific product. The brilliant investigations of Oersted and Faraday on the relationships between electricity and magnetism, done early in the nineteenth century, were pure scientific research. Neither man would have dreamed of the technological applications made of their research in telephone and telegraph communications alone. The knowledge about penicillin's antibiotic power or the relationship between electricity and magnetism is scientific - the application or socio-cultural use is technological.

Implications of the Science - Technological Dichotomy

Because of the public nature of the knowledge of science, it becomes an entity whose use is utterly dependent on the whim and moral discretions (or indiscretions) of anyone or any group intelligent enough to make use of that knowledge. Science cannot and should not bear the responsibility for technological tragedy or triumph. Society uses both science and technology for its own purposes - good or bad. Man himself must claim credit for the outcomes of his technological uses of scientific information. Human beings, not science or technology, must assume responsibility for their own destiny based on their own value-ridden decisions. The scientist

SCIENCE-TECHNOLOGY RELATIONSHIP



as a scientist has little control over how society chooses to use the products of science. He operates only within the ethic of empiricism. There are those who would like to place immense responsibility as to how knowledge is used on the scientific community. To do so is to fail to understand the empirical base of the discipline itself. The scientist can often sway public opinion with his immense knowledge but he does not control society any more than any other intelligent person.

One of the most classic cases of this lack of control is probably the story of Alfred Nobel, the chemist who developed dynamite in 1867. This development, in Nobel's mind, would become a useful instrument for social good. But, social destruction substituted for much of Nobel's naive desire. Death and destruction were partners with the political decisions to use dynamite for war. Nobel hated this but had no control over the ways society chose to use dynamite. As a

consequence of his guilt-ridden conscience, Nobel set aside some $9,000,000 in an interest-bearing fund. The interest from this fund goes to award the annual Nobel prizes for peace, medicine, and many other fields. The point here is simply Nobel's complete inability to control his own discovery. To say that any scientist or technologist must bear total responsibility for the cultural applications of his finding is as absurd as trying to bring Orville and Wilbur Wright back from their graves to stand trial for a major air disaster.

The answers to man's most perplexing problems lie not in science or in the irrational ethical demands placed on scientists - the answers lie in the ways in which knowledge is used and the manner in which humans behave. These are socio-political and technological considerations for the most part and not scientific ones! Every member of society should realize that science is solely an empirical, intellectual act of man. Science is nothing more than the processes man uses to generate scientific knowledge and the product or scientific information generated. Science cannot solve problems; it can only provide the information for man to choose to use. Just as science bears no blame for causing man's problems, it also accepts no responsibility for solving man's problem situations. Humans cause their own problems; it is up to them, not science, to find successful solutions to the problems they have created. It is imperative for all human beings to conceptualize science and technology in this manner as well as to correctly perceive its potential and its limitations.

Implications For Elementary Teachers

The above discussion in terms of the differences between science and technology and the varying ethics of each may be the most single important idea about science generated in this methods book. If teachers of science have clear concepts of science and technology, they, in turn, can transmit these concepts accurately to their students. Teachers can then plan for a science program that accurately reflects the essence of science. Teachers will have the ability to point out where technological applications of science have been made and how they relate to the scientific enterprise. You, as elementary teachers, have a unique and important opportunity to clarify your own thinking and influence the understanding of your students.

> When we fall into the trap of believing or, more accurately, hoping that technology will solve all our problems, we are actually abdicating the high touch of personal responsibility. Our technological fantasies illustrate the point. We are always awaiting the new magical pill that will enable us to eat all the fattening food we want, and not gain weight; burn all the gasoline we want, and not pollute the air; live as immoderately as we choose, and not contract either cancer or heart disease.
>
> In our minds, at least, technology is always on the verge of liberating us from personal discipline and responsibility. Only it never does and it never will.
>
> John Naisbitt
> Megatrends, 1982

PART II

Why Teach Science To Children?

Performance Objectives

Subsequent to your interactions with Part II, you will be expected to be able to . . .

1. . . . define the term "general education" and identify characteristics of a general education which would be important for the child and society as a whole.

2. . . . synthesize and communicate a definition of "scientific literacy" from your reading and analysis of Part II.

3. . . . explain how "scientific literacy" differs from the traditional definition of "literacy" in education.

4. . . . identify or list the four goal cluster headings found in Project Synthesis. Further, be able to describe what is meant by each of the goal cluster headings.

5. . . . present a clear, concise argument for using the Project Synthesis goal clusters as a focus for preparing a sound science program for children, i.e., why do the goal clusters represent "scientific literacy" in today's society?

6. . . . write a minimum of two possible subgoals for each of the four Project Synthesis goal clusters which would be appropriate for the elementary school (K-8).

7. . . . identify, define, and defend a minimum of four science concepts which would be important for scientific literacy. (These concepts need not be taken from the worktext but, if not, your argument for using them must be sound.)

8. . . . identify several dividends available to the teacher who teaches an experiential science program based on the concept of scientific literacy. Further, be able to describe how each of these dividends has payoff for the teacher and the child.

Why Teach Science To Children?

In the opinion of the writers, the only good argument for educating children in the first place is to provide them with a sound "general education". What is that? A good general education is one which provides human beings with the knowledge and skills which will enable them to be effective and well-adjusted members of society both today and tomorrow. This strongly infers that there must be some very generalized bodies of knowledge and skills which are important in the lives of all human beings. It also infers that the elementary school should probably not be an institution for specializing and segregating children academically in order to reach different goals for different groups. The entire premise of "general education" is one based on the notion that a common preparation for life is of paramount importance and that the components of this curriculum can be identified and operationally defined.

It follows that all major instructional areas existing in today's elementary schools are considered of value by society for general education purposes. Whether or not this is the case, one can observe that science is finding an ever-increasing role in the nation's schools and, therefore, it must be considered an integral component in a child's general education.

As important as science is, it is by no means consistent across the schools of America. Nor can we always observe science being taught. There are times when the preservice teacher - and, indeed, oftentimes the inservice teacher - finds it difficult to provide a sound argument for science instruction. In fact, science often takes a "back seat" to other curricular areas and does so for a wide variety of reasons. These reasons include the "back to basics" argument so often heard today, the "lack of time for science" position, the teacher's feeling of insecurity with science, or simply a lack of motivation on the part of the teacher to provide science instruction. The writers believe that most of the reasons for ignoring science or arguing its value are faulty and stem from a basic lack of understanding of what science is, its role in man's society, and its impact (and potential impact) on children.

Part II of this worktext, therefore, is designed to discuss science from a general education perspective and to help eliminate the faulty perspectives concerning science so often observed in both pre- and inservice teachers. Because of this, the writers ask that you carefully consider the positions which follow and the logic behind these positions. Of paramount importance is your own professional responsibility to clarify your understanding of science and its role in a general education. Only by achieving such clarification can you teach science in order to maximize its potential for elementary school children both today and tomorrow.

Scientific Literacy - The Major Consideration

Science has had and is having a tremendous impact on man and his culture. Whether we like it or not, every child and every adult must be able to cope each and every day in an environment that is science and technology oriented. This fact alone is probably a sufficient argument for placing an emphasis on science in the elementary school.

As meaningful as this argument may be, the writers believe that there are many other reasons for incorporating science in the curriculum. However, all of these reasons may be discussed under one overall heading. This heading is commonly termed "scientific literacy". Of course, "literacy" in this context goes beyond the constraints normally placed on a definition of literacy. It is much more than being able to read and write about science.

As a teacher preparing to teach science you would think that there would be a definition of "scientific literacy" which has found agreement across the educational community. You would hope that this definition is easily understood. You would also hope that all commercial science programs prepared for children are well equipped to help you teach for "literacy". Unfortunately, none of these things are true. This may cause you concern and frustration at first. But, let's see if we can begin to make sense out of all of this.

The Best Definition of Literacy - Something called Project Synthesis

Of all of the scientific literacy definitions which exist, the best one is probably contained in a recent document published by the National Science Teachers Association (1981). This document - What Research Says to the Science Teacher, Vol. III - reports on a thorough research study called Project Synthesis. Project Synthesis was funded by the National Institute for Education, U. S. Department of Education.

Project Synthesis was headed by a reputable science educator from the University of Colorado, Dr. Norris Harms. Dr. Harms worked with a team of 23 science educators in order to draw together and interpret existing research and literature on the status of science instruction in the United States. This synthesis effort drew upon three major studies sponsored by the National Science Foundation and data provided by the National Assessments of Educational Progress in Science.

Project Synthesis, therefore, represents a responsible and sophisticated effort to identify major goals for science instruction in North America. Project Synthesis focuses on five separate areas involved in science education (i.e., elementary science, biology, the physical sciences, inquiry, and the interrelationships between science, technology and society). The report discusses each of these areas as they relate to the four educational goal clusters deemed crucial for all students. It is these goal clusters on which we will focus here.

But first, a note of explanation to help you weave your way through these goals. First, the goal clusters will be stated and described. Second, example educational goals will be listed under each cluster. Third, specific instructional objectives or outcomes which could be written for these goals will be listed. In no way are these complete listings of goals and outcomes. Only the four goal clusters themselves are exhaustive. Let's begin.

The Goal Clusters of Project Synthesis

GOAL CLUSTER I - Personal Needs.
Science education should prepare individuals to use science for improving their own lives and for coping with an increasingly technological world.

GOAL CLUSTER II - Societal Issues.
Science education should produce informed citizens prepared to deal responsibly with science-related societal issues.

GOAL CLUSTER III - Academic Preparation.
Science education should allow students who are likely to pursue science academically as well as professionally to acquire the academic knowledge, skills, and attitudes appropriate for their needs.

GOAL CLUSTER IV - Career Education/Awareness.
Science education should give all students an awareness of the nature and scope of a wide variety of science and technology-related careers open to students of varying aptitudes and interests.

The Project Synthesis group intended that these four goal clusters be used as axioms from which subgoals and statements of student outcomes (instructional objectives) would be derived at the local level for science programs, courses and assessments of educational progress in science. In this way local education agencies would have the flexibility to operationalize citizen scientific literacy as it best fits the needs of their students. Example subgoals and outcomes that might be stated at the local school level are provided below for each of the respective goal clusters.

GOAL CLUSTER I - Personal Needs - Possible Subgoals. Subgoals associated with Goal Cluster I, Personal Needs, could include:

SUBGOALS

1. concepts associated with the impact of science and technology on one's life and on society;
2. the ability to use science to help solve everyday problems;
3. the ability to use science in making everyday decisions;
4. valuing and persistently trying to maintain a healthy body; and
5. the ability to be a successful consumer in a scientific society.

Possible Student Outcomes (Objectives). Possible outcomes should include evidence that the student can:

1. demonstrate specific ways in which an individual can decrease energy consumption in the home;
2. use data from a variety of sources to make decisions about personal health problems;

GOAL CLUSTER I

OUTCOMES

3. modify belief systems or attitudes based on new scientific evidence;

4. compare technologically-related information sources and communicate ways in which they are similar and/or different, and

5. apply knowledge of energy expenditures in the production and distribution of food to his/her consumer practices.

GOAL CLUSTER II - Societal Issues - Possible Subgoals. Subgoals associated with Goal Cluster II, Societal Issues, could include:

SUBGOALS

1. the development of an appreciation for both the potential and the limitations of science with respect to solving societal issues;

2. the acquisition of both the knowledge and skills needed to deal with the environmental and energy issues affecting society;

3. the development of a sense of custodianship for protecting and preserving the natural world with which science is concerned;

4. an understanding of the desirability of considering various alternative value perspectives concerning science-related social issues; and

5. an understanding of the very real relationship that exists between quality human life and quality of the environment.

GOAL CLUSTER II

Possible Student Outcomes (Objectives). Possible outcomes could include evidence that the student can:

OUTCOMES

1. compare two or more information sources related to a particular science-related societal issue and communicate likenesses and differences observed in the comparison of those information sources;

2. analyze alternative solutions to science-related societal issues and correctly determine which of those solutions would best represent both a quality of human life and a quality environment;

3. analyze personal behaviors and communicate the cultural and ecological implications of those behaviors;

4. investigate a science-related societal issue and determine what the main value perspectives (alternative viewpoints) are with respect to that particular issue; and

5. communicate the effects of various drugs used to modify human behavior and the need for social controls over those which are harmful to human beings.

GOAL CLUSTER III

SUBGOALS

GOAL CLUSTER III - Academic Preparation - Possible Subgoals. Subgoals associated with Goal Cluster III, Academic Preparation, could include:

1. the acquisition of major scientific ideas (including theories, laws, and models);
2. the development of those intellectual skills (cognitive processes) needed by the scientist in the pursuit of scientific knowledge;
3. the development of a respect for empiricism and the scientific attitudes associated with it;
4. the knowledge that certain scientific explanations of phenomena have had to be altered as a function of new evidence/data; and
5. the ability to evaluate the empirical quality of information which has been gathered by experimental means.

OUTCOMES

Possible Student Outcomes (Objectives). Possible student outcomes could include evidence that the student can:

1. observe a simple experiment and communicate whether adequate controls have been used in the data collection process;
2. interpret data presented in the form of functional relationships such as those found on data tables and in graphs;
3. infer empirically sound explanations for observed phenomena;
4. communicate major observations which led to the germ theory of disease and the impact that this theory has had on biology and medicine; and
5. communicate the differences that exist between empirical truth (knowledge) and other sources of human truth (knowledge).

SUBGOALS

GOAL CLUSTER IV - Career Awareness - Possible Subgoals. Subgoals associated with Goal Cluster IV, Career Awareness, could include:

1. the ability to make informed career decisions regarding jobs related to both science and technology;
2. the understanding that both sexes, all ethnic groups, a wide range of educational and ability levels, and various handicaps can and do obtain positions in scientific and technological fields;
3. an awareness of scientists and technicians as real people;

4. an understanding of the role played by a broadly-based education in becoming ready for science/technology-related careers; and

5. an awareness of where further information on a wide variety of science/technology-related careers can be obtained.

Possible Student Outcomes (Objectives). Possible outcomes could include evidence that the student can:

GOAL CLUSTER IV

OUTCOMES

1. observe a particular career scientist or technician and carefully examine the potential of that career in terms of a future interest in it;

2. communicate why it is important for an individual working in science to be extremely curious about natural phenomena;

3. communicate why careers in science can accommodate a wide variety of student academic interests;

4. decide and communicate what the main issues are in selecting a particular career in science and technology; and

5. communicate how careers in certain fields such as conservation medicine, nutrition, nursing, sanitation, horticulture, pest control, etc. are related to science.

A SCIENTIFICALLY LITERATE PERSON: A DEFINITION

Using the Project Synthesis goal clusters as our model, we can define a scientifically literate individual as: (1) one who can use science for improving his/her own life and for coping with an increasingly technological world, (2) one who can deal responsibly with science-related societal issues, (3) one who has acquired the academic knowledge, skills, and attitudes appropriate for the pursuit of science, and (4) one who is aware of the nature and scope of a wide variety of science-related careers open to students of varying aptitudes and interests.

The science educators who worked on the elementary school portion of Project Synthesis held the view that all four of the goal clusters should be emphasized in the elementary school. In order for them to work successfully, these educators felt that science should excite the child's natural curiosity, foster an interest in the student's environment and in the human organism itself, and provide opportunities for actually doing science in the classroom. The challenge of Project Synthesis is an imposing one but one with which the authors of

your worktext agree emphatically. And, it demands a teacher who is committed, well trained, and unafraid to learn along with the children. Can you be this kind of a professional? Only you can answer this question.

More on Literacy - Some More Examples

As you read earlier, the subgoals and student outcomes listed under the four Project Synthesis goal clusters were merely examples of content and objectives that would be appropriate to this very fine definition of scientific literacy. Needless to say, there is much more that can and must be incorporated under these goal clusters.

The section you are now reading will provide you with some additional content (more examples) that the writers believe should be included in a sound science program based on the concept of scientific literacy. It must be made clear that this section is by no means complete. (For example, major emphasis is placed on societal issues as they relate to environmental concerns later on in this worktext.) However, this section does include examples of science content that the authors firmly believe should be reflected in the elementary school's science program. It should also expand your understanding of science and its role in the lives of all human beings.

As you read through this section, please try to determine where these literacy components would fit under the Project Synthesis goal clusters. If you believe that certain components have merit for more than one goal cluster do not be concerned. Some most certainly do.

THE EXAMPLES:

Five Major Literacy Components

A scientificially literate human being can be described as one who. . .

(1) . . . has a correct concept of what science is and what it is not. As noted earlier, science is simply a special way of investigating the objects and events of the universe. It is based on a philosophy of what reality is and this philosophy dictates some rules that must be respected when man searches for scientific knowledge. A critical basis of science is its empirical nature. Empiricism is observation or experimentation oriented. And, similarly, knowledge can be empirical only if it can be replicated. This means simply that the observation or the experiment can be repeated and shown valid.

Scientists also believe that man must consider knowledge to be tentative. The scientists believes that knowledge is subject to change. Interestingly, children (and some adults, too) believe that scientific knowledge has absolute truth value, i.e., not to be doubted or questioned. This is not the case at all! Most scientific knowledge is inductively derived knowledge and subject to change as a result of new observations. Much of what scientists "know" is constantly being modified as a function of new information.

In addition, scientific knowledge is usually perceived as being probabilistic. Here, again, we see a characteristic closely allied to the tentative nature of knowledge in science. Much of what we derive from research is a function of

probabilities. A tremendous amount of the knowledge in the behavioral sciences (e.g., educational research and psychology) is a function of probabilities rather than absolute, dogmatic conclusions. How often do you hear something like, "One who smokes two packs of cigarettes a day will have a greater probability of respiratory disease than. . ." This statement is based on probabilities rather than on certainties. This is what science is all about. It permits man to predict future happenings with a high level of confidence.

And, finally, scientists believe that scientific knowledge should be public. This is an ethic which is sometimes violated by the scientific and industrial community but one which is a basic belief nevertheless. Probably the most prevalent reason for arguing for public knowledge is one closely associated with replicability. If knowledge is made public, its "goodness" or accuracy can be tested by other scientists under similar conditions.

(2) . . . understands the relationships which exist between science and technology and how these pursuits influence society. Among other things, children should understand that there are striking differences between science and technology. At the same time, the child should understand that science and technology tend to support each other and that the relationship between the two is a close one. This is rather like looking at both sides of the coin, and it is imperative that this be done.

Allied with the above, the writers firmly believe that citizens (young and old alike) must realize the tremendous limitations of science and technology. Far too many people tend to see science and technology as omnipotent or all-powerful although this is totally absurd. This perception tends to permit citizens to foolishly rely on science and technology to solve many of the persistent problems facing man. In reality, science and technology are man-controlled and capable of solving only those problems which are amenable to investigation and solution by technological means. Most of man's problems must be faced squarely by man acting in consort with other human beings in a citizenship capacity and not by relying on either science or technology. It is imperative to help youngsters realize that they cannot abdicate their own responsibilities to science and technology.

Further, it is important for human beings to realize that the activities of science and technology are controlled by society. Society has certain needs and these are often translated into demands on science and technology. These demands can be humanistically oriented, politically oriented, economically oriented, or combinations of these. Of course, a good deal of what science researches is science-oriented - science for its own sake so to speak - the search for knowledge as a function of man's curiosity. This basic curiosity has led to some of the most startling discoveries ever made. Consider the X-ray, the research leading to the theory of evolution, space exploration, nuclear fission, etc.

Closely associated with the above characteristic of science is another that deals with the value of scientific knowledge. Oftentimes what science discovers seemingly has little merit as far as technology or society is concerned. However, time after time, seemingly valueless knowledge has turned out to be of considerable importance later on. Many, for example, believe that the nation's space program is a waste of money. The space shuttle program alone is proving this to be faulty thinking. And, what breakthroughs lie ahead in harnessing the vast amounts of energy that exist throughout the universe? Could the seemingly silly research on solar winds provide man with a basically free transportation energy source down the road? Are the natural resources of the moon and Mars possible resources for man on earth in another twenty years? Can what we have learned

about man's physical reactions in space be converted to save lives on earth? On and on. . . The vast backlog of scientific knowledge being gained in a multitude of research studies can have tremendous consequences for man's own survival in the future.

(3) . . . understands and can apply key concepts of scientific knowledge in his daily life. Knowledge, in part, permits man to acquire new knowledge. This, of course, is done via the process-product cycle with which you are already familiar. Knowledge also helps free man from the chains of superstition. Although there is no complete agreement on the constituents of this literacy component, it is obvious that certain key concepts are of great importance. A few of the concepts which the writers and others perceive to be important follow for purposes of example.

The idea that things happen in the universe because of cause and effect relationships appears crucial. The cause and effect concept has a close relationship to understanding that the universe is more or less orderly and that happenings can be predicted with high degrees of probability. Naturally, this idea should also have the impact of allaying many of man's superstitions.

Concepts dealing with the relationships between matter and energy also appear critical to literacy. Human beings interact with these relationships each and every day of their lives. What are the relationships? Can matter and energy be universally conserved? Are there exceptions to this conservation? What are the implications of these ideas to human beings as they interact with the environment?

The concept of homeostasis should probably be considered as a key concept in the literacy dimension. Homeostasis can be defined as a state of equilibrium or a tendency toward such a state between different but interdependent elements. On the surface, this appears to be quite an idea - too difficult, perhaps, for children. Not true! A healthy organism is homeostatic. The bits and pieces of that organism are working together successfully - in equilibrium if you will. More importantly for children, perhaps, is the notion of homeostasis as it involves their environment. Are living communities becoming less and less balanced as a function of man's activities? Or, are they able to sustain homeostasis? Is man in a homeostatic relationship with the biosphere or are there severe threats to this equilibrium? The ecological implications of homeostasis are significant and of importance to every man, woman, and child on the planet Earth.

Concepts concerning both asexual and sexual reproduction seem appropriate for a list of key concepts. All living species must be able to reproduce themselves or become extinct. Further, man is a reproducing organism. That children should understand the basic principles of reproduction seems critically important. Note that the writers are not confusing reproduction with sex education. Sex education holds a much broader amalgam of concepts than reproduction per se.

The examples stated above represent only a small number of those concepts which are often perceived as important from a literacy perspective. Others might include such things as evolution, work, the organism, population, community, ecosystem, pollution, time-space relationships, relativity, and behavior.

(4) . . . understands and can use the science processes associated with basic inquiry or problem-solving strategies. When we speak of science processes

we are dealing with those intellectual skills used by the scientist as he goes about the business of doing science. These processes are closely allied with what educators term "critical thinking". And, they probably have application (transfer potential) to all aspects of human activity which means that the processes of science can be used in problem solving activities beyond science. However, it may well be that science education can do a great deal to foster critical thinking in the human being and help students maximize their intellectual potential. This could be the major contribution of science in the elementary school curriculum. Whether or not science contributes to critical thinking ability in students depends entirely on whether these thought processes are taught and, therefore, actualized. This is not an easy task but it is certainly possible!

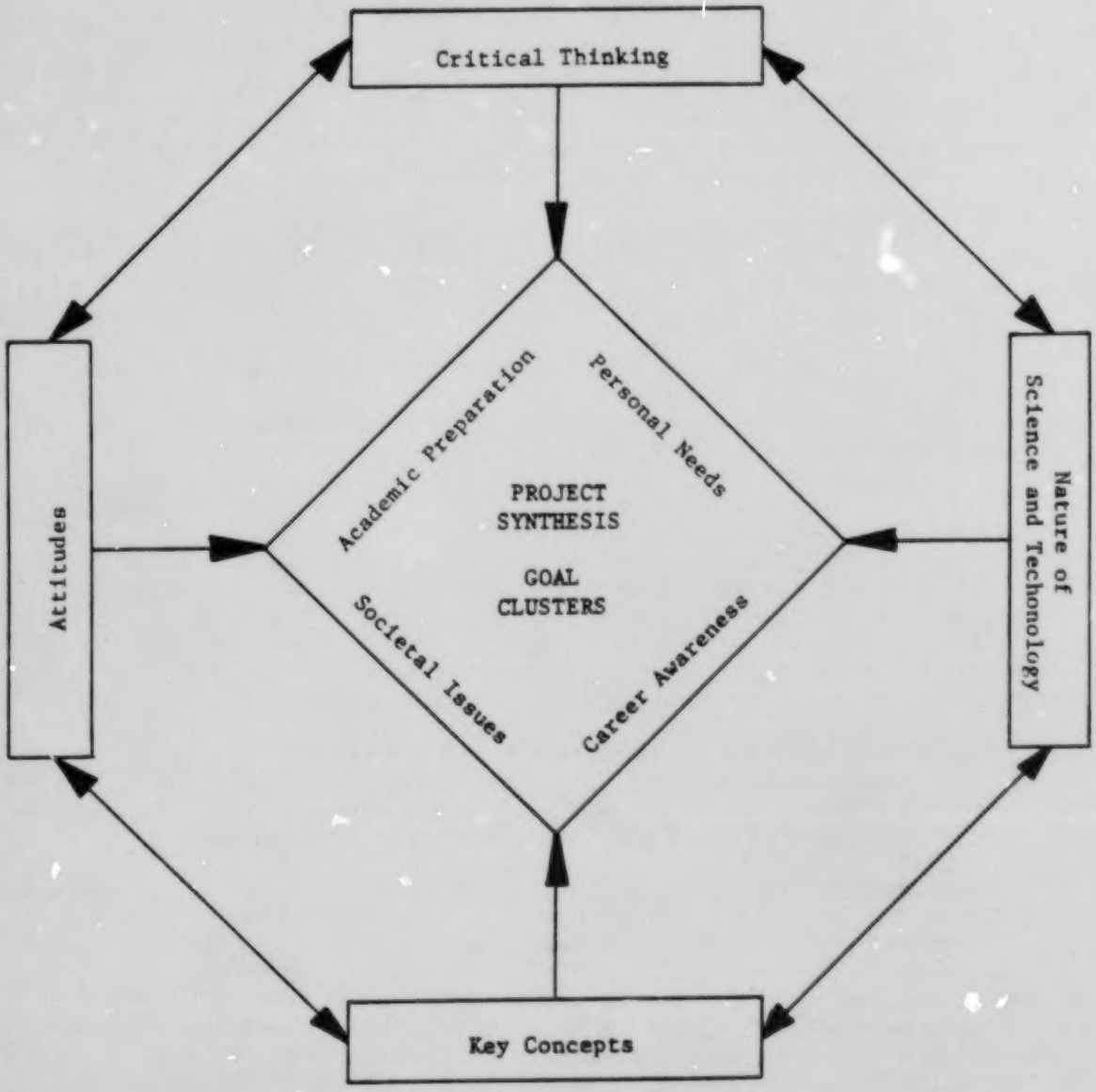
Because an entire chapter in this worktext deals with science process the writers will provide only a generalized description of these here. Science process includes such intellectual activities as observing, comparing, classifying, inferring, hypothesizing, designing and conducting experiments, predicting, and measuring. Those of you who learned in school that there was such a thing as a "scientific method" will be quick to note that many of these processes were referred to as part of that method. Today, however, most science educators take the position that there are many methods in science and that different scientific activities utilize different sets of processes.

(5) . . . appreciates and can apply the basic attitudes of the scientist. Certain values operate in science and these values are reflected in the more commonly held attitudes of scientists as they engage in research. Some of these values relate directly to the logic behind empiricism. Others are values held by the individual who is motivated to be involved in science itself. Basic curiosity is one of these and is closely allied to man's longing to know and understand. This attitude is often based on the premise that knowledge has value and that empirical inquiry should be undertaken to obtain that knowledge.

Another value is that associated with the demand for verification. A scientist often rejects knowledge that cannot be supported with hard data. At the very least, the scientist suspends judgment on a finding or theory until enough data are available to lend substantial support for the new knowledge.

Most scientists have a sincere respect for empirical logic. Here the scientist insists that conclusions drawn from scientific work be based on a logical frame of reference with respect to available data. At the very simplest level, this characteristic is demonstrated by the insistence that an inference drawn from an observation be based on the logic of the situation rather than on intuition. In this way, scientific knowledge differs from dogmatic or intuitive knowledge. And, this is a difference that is critical to all of the activities of science. It is this, perhaps as much as any other single thing, that separates science from less empirical intellectual pursuits.

A MODEL OF SCIENTIFIC LITERACY



More Dividends For the Science Teacher

In the opinion of the writers, there is as much potential payoff for teachers in the teaching of science as there is for the students engaging in it. The unfortunate aspect of this opinion is that this payoff is often not identified by teachers and, therefore, remains unclaimed in the classroom.

There is no question about the hard work involved for the teacher who teaches an experiential, hands-on science program for children. It is much, much easier to ignore science or to relegate it to a "let's read about science" type program. For those teachers who are willing to expend the energy necessary to provide a hands-on program, there can be some payoffs that are extremely beneficial. A brief discussion of some of these follows. Several of these so-called "payoffs" will be dealt with in more detail later in the worktext.

An experiential science program is normally very motivational for students. This is understandable because in a hands-on situation students are "doing" instead of reading and/or writing about science. Since several modern science programs are highly inductive in nature, science is also a time of discovery or learning by doing. There is a definite motivational potential here for many students because they are actively involved in the learning process.

Teachers who have been teaching from the textbook and have, for one reason or another, switched to hands-on approach, have found it difficult to return to the textbook as the principle focus for the science program. Once having experienced the doing of science, students are very reluctant to go back to a reading-oriented program.

Those teachers who make a practice of approaching the educational experience from an interdisciplinary perspective find that science content is an excellent vehicle for use in other content areas. Science as a content vehicle has potential for skill development in reading, social studies, language arts, and mathematics. Students are given an opportunity to draw upon their science knowledge for the development of experience charts in reading, various communication activities in the language arts, and in problem solving in mathematics. Because most children seem inherently interested in many science topics, they are prone to utilize these interests in the development of skills in other areas to a much greater extent than if the content used is of only a passing interest. Science subject matter is also generally free of age restrictions. Research tells us that young children are extremely interested in animals and that this interest tends to hold up well into the junior high school years. Other topics are also well-suited for use as content vehicles, e.g., space exploration, fossils, prehistoric life, earthquakes and volcanoes, and reproduction (in the adolescent years).

Teachers who supplement their regular textbook fare with reading, language, or math activities drawn from science are sometimes amazed to find that the children gain a vocabulary which would generally be thought to be much too advanced for students of their ages. Why would this be the case? It's probably a matter of the children understanding the concepts involved in the content being used. When this is the case, children are not normally too concerned about the difficulty level of the words involved. In other words, with respect to vocabulary, the children have "intellectual pegs to hang their memories on". In this situation, vocabulary development seems to become almost automatic instead of the typical drudgery so often associated with it.

The writers of your worktext are reminded of the first grade teacher in Illinois who was using fossils as a content vehicle in reading via the experience chart method. Her students had handled fossils and had seen a filmstrip on fossilization and how scientists went about the business of studying fossils. She reported that, during the writing of the experience chart, the students wanted to use the word "paleontologist" in their story. Further, she reported, "I would have used the word without hesitation except that I couldn't spell it."

The writers have already mentioned the transfer potential of those critical thinking skills that can be taught via science. For the teacher who is sincerely committed to teaching critical thinking, science may well be the one most important tool at her/his disposal. This is not because science is the only area in which critical thinking can be taught. It is simply because there are probably more programs available for doing this in science than in any other content area. Of major importance, however, is the very real potential for helping students learn how to transfer these skills to other content areas, e.g., social studies, language arts, and math. The teacher who is teaching science process skills (critical thinking) in science and who helps students see how these same skills can apply to problem-solving situations in other content areas, is probably the teacher who is truly helping children become more capable problem-solvers, i.e., critical thinkers. Therefore, the idea of teaching science process for the sake of science learning is only the beginning in the classroom where the teacher recognizes the need for critical thinking in other content areas as well.

In Summary

Sound science instruction in the elementary school has payoff value for both youngsters and the teacher. The major consideration for teaching science to children is something the writers term scientific literacy. In this context, however, literacy goes beyond the normal constraints placed on the term. Project Synthesis identifies four major areas of concern (goal clusters) for the elementary teacher. These are: (1) meeting the personal needs of children; (2) developing students who can deal responsibly with social issues, (3) providing for academic preparation in science, and (4) providing the awareness regarding science and technological careers. As we have seen, these goal clusters can be used in formulating a definition of scientific literacy.

Scientific literacy also includes elements like understanding science and the scientist, being able to differentiate between science and technology, understanding and being able to use the processes of science, and knowing and applying the basic attitudes of the scientist.

With respect to payoff for the teacher, science has potential for being very motivating for use as a content vehicle in other subject matter areas, and for serving as a model to be used to teach critical thinking which can be applied to all aspects of human endeavor.

> The rapid progress true science now makes, occasions my regretting sometimes that I was born so soon. It is impossible to imagine the height to which may be carried, in a thousand years, the power of man over matter . . . O that men would cease to be wolves to one another, and that human beings would at length learn what they now improperly call humanity.
>
> Benjamin Franklin - 1780

PART III

A Short History of Elementary Science Methods in the United States

Performance Objectives

Subsequent to your interactions with Part III, you will be expected to be able to. . .

1. . . . identify or define: (A) natural history, (B) anthropomorphism, and (C) teleology. Further, be able to explain the roles these have played (if any) with regards to religious education, object teaching, the Nature Study movement and children's literature.

2. . . . compare and contrast (noting similarities and differences) the object teaching period in science education and the Nature Study movement. (One of the elements included in this comparison must be the role of "faculty psychology".)

3. . . . identify and/or describe those suggestions set forth in the early 1900's by Dewey and Craig which were aimed at improving elementary science education. Further, be able to explain the net effect these ideas had on actual in-class elementary science instruction.

4. . . . describe or identify the impact of the successful launching of Sputnik on science education in the United States.

5. . . . describe or identify the major goal(s) of the "big three" science programs funded by the National Science Foundation (NSF). Further, be able to explain how these programs differ from traditional elementary science textbook programs.

6. . . . communicate the similarities and/or differences between the "big three" science programs and commonly used elementary science textbooks.

7. . . . describe the current status of science education according to Project Synthesis and provide reasons as to why this state-of-affairs seems to exist.

8. . . . communicate where we now seem to be headed in elementary science education in the USA and why this is the case.

9. . . . synthesize and communicate a succinct record of the major eras in science education along with the basic characteristics of each era.

* The authors wish to thank Drs. Trudi L. Volk and William J. Bluhm for their efforts in helping prepare Part III of this worktext.

A Short History of Elementary Science Methods in the United States

In the Beginning - The Didactic Era

The beginning of science education for children in the United States can be traced as far back as the late 1700's. Children's books, called the children's literature or the didactic literature, were the first method of elementary science education. These books were originally of British origin. Many of them were brought to the United States and were adapted to the new world and reprinted by American publishers.

The early American versions of the didactic literature had several purposes. One such purpose was to develop ethics, morals, and manners in youngsters. Within the stories children were shown the value of neatness, unselfishness, amiability, honesty, carefulness, etc. Another purpose of the children's literature was to stimulate the child to develop, on his own, some of the critical thinking skills such as observation, comparison, and experimentation. Transmitting scientific information, concepts, and principles from the written page to the child's head was yet another purpose of the didactic literature. Such topics as animals, plants, the solar system, seasons, and refraction of light were among those covered in the children's books.

Religious Influence On Early Science Education

During the time that the didactic literature was being printed in the United States, religion was a dominating influence on people's lives. This domination was reflected in the children's literature. Children were taught a reverence for natural history, i.e., the objects and events of nature. It was believed that by developing a reverence for nature the youngsters would develop a reverence for God at the same time, since God was the creator of the universe including all of the natural world.

Additional religious influence of this era on the children's literature can be seen in terms of anthropomorphic and teleological references. The practice of tendering human characteristics to other life forms - anthropomorphism - was a common one. Thus references like the sly fox, the busy bee and the wise old owl crept into children's reading matter. Anthropomorphic references were to serve as models, after which children could pattern the building of their own characters. Another common practice of the era was to explain a phenomenon teleologically. That is, naturally occurring objects and events were explained in such a manner as to make the reader perceive that they were predestined to be that way. A tree, for example, grows where it does to provide shade for children. The cow is here to give milk for people to drink. A storm is God's will.

Even in present day literature, one can still find anthropomorphic and teleological references made to the objects and events of nature. However, the professional opinion today is to eliminate both from science literature because they tend to promote inaccurate and even debilitating conceptual perceptions of the universe.

The didactic literature, at its inception, was designed to be used by private tutors or parents who taught children at home. Financially, the children's

literature was within the reach of only the upper classes. As time proceeded and the books were adapted for use in school classrooms, much of the scientific content was kept, but unfortunately development of the scientific skills such as observation and experimentation were emphasized less and less. The adapted books, as school materials, had become readers, the purpose of which was to transmit information, not critical thinking skills to the students.

Object Teaching

About the same time that the didactic literature was being adapted for classroom use (1860), the "object teaching" movement was beginning to sweep through Europe and the United States. This movement was started by Pestalozzi, a Swiss of Italian parentage. A classic description of Pestalozzian object teaching is given by Krusi[7] when he states:

> To place objects before them (children) in which they are interested, and which tend to cultivate their perceptive faculties; and, at the same time, lead them to name the object, to describe its parts, and to state the relation of these parts. Thus language is also cultivated; and, from the observation of a single object, the pupil is lead to compare it with others, and the first steps in classification are taken.

In the United States the best known adaptation of Pestalozzian object teaching was developed at Oswego, New York. The newly formed National Education Association supported the Oswego object teaching and so it received nearly total acceptance across the country. Object teaching was based on a child's limitations rather than his capabilities. It was thought that elementary school children could think only in terms of the concrete, not the abstract. Further, it was believed that children could not interpret events or phenomena.

For its content, object teaching turned to the objects of natural history - rocks, minerals, plants, and animals. Objects, once placed before the children, were closely and continuously observed. Likenesses and differences were noted, described, and memorized. This was, therefore, an era in which description was the key element rather than interpretation or investigation into the cause and effect relationships of the universe.

Faculty Psychology - The Basis of Object Teaching

Object teaching was based on and supported by the principles of faculty psychology. "The emphasis on observation and memorization for very young children was based on the sequential development of capacities. It was falsely assumed that young children were able only to observe and identify objects but were unable to reason or to interpret phenomena".[10] Furthermore, faculty psychology put forth the notion that the mind was a muscle that could be strengthened by exercise. Therefore, during the object teaching era, school children observed, compared, memorized, and described over and over again in an attempt to strengthen their brains.

As a method of teaching science, many contemporary writers came down hard on object teaching and its faculty psychology basis. Certainly, the psychological premise for object teaching was faulty. We know, for example, that children can intellectually manipulate basic principles of science and can interpret happenings and see relationships. Further, to focus solely on the strategies of object teaching is absurd from a general education point of view. Still, research indicates that the strategies of object teaching (critical observation, comparison, and communication) can help develop perceptual ability and, further, that these skills are retained over long periods of time and that these same skills can be transferred to new and unique situations. Thus the strategies of object teaching cannot be totally rejected for they may have some payoff value in terms of development and use of certain critical thinking skills.

Science Curriculum Failures

In the late 1800's, America was in the midst of industrial expansion. Citizens were viewing first-hand the practicability of new scientific information and its technological applications, e.g., railroads, agricultural machinery, the telegraph. As a result of science and technology's practical implications, citizens were demanding that the content of elementary school science be broadened and organized. The great interest that had been given to object teaching in the 1860's had begun to wane and with taxpayers calling for a new curriculum, object teaching began to fall by the wayside.

For about the next thirty years (1870-1900) prominent educators spent their time attempting to develop science programs. These programs tried to expand and organize science content. Further, these new science programs included the development of critical thinking and problem-solving skills. However, due primarily to the inability of teachers to handle these new science programs, they failed to become implemented.

The Nature Study Movement

While the above mentioned elementary science programs were failing, a new elementary science thrust, the Nature Study movement emerged in response to an industrial America. As large cities grew around booming industries, young rural adults were attracted by the employment, entertainment, and excitement the cities offered. A tremendous migration toward the cities took place with the attendant problems of city crowding and unemployment.

Nature Study enthusiasts felt that if young children could be imbued with a deep appreciation of natural history they would not leave the farm for the city. Further, the Nature Study movement was aimed at improving agricultural practices, thereby stimulating the rural economy. Centered at Cornell University and headed by Liberty Hyde Bailey, the Nature Study movement provided teachers with the materials they needed to successfully teach about nature, i.e., Nature Study manuals, supplementary readings, and study guides.

The content of the Nature Study science program was, like that of object teaching, the things of nature. The material was, however, better organized and more accurate. Although the Nature Study's content was sounder than that of the object teaching era, the method of instruction was still that of object teaching

based on faculty psychology. Observation, comparison, memorization, and description were once again performed over and over by students. Also, as before, the children were viewed in terms of their limitations rather than in terms of their capabilities.

Nature Study's aesthetic goal was to get children to love, respect, and protect nature. To achieve this goal, the Nature Study movement became interdisciplinary. Poetry, singing, painting, and writing were incorporated into lessons. Whether the Nature Study movement was successful or not in saturating children with knowledge about and respect for nature, the movement began to decline by the 1920's.

New Faces And New Ideas

During the second and third decades of the 1900's, men of stature set forth ideas that have affected elementary science education to this very day. Dewey's ideas about elementary science education were representative of his "learning by doing" philosophy. He believed that scientific knowledge separated from the scientific processes which generated that knowledge became, ". . . a body of inert information" when presented to students.[4] Further, he pointed out that the methodology of science (science processes) was as of great, if not greater, importance to the education of children than the knowledge of science.

In 1927 Gerald Craig (from Columbia University) published his dissertation Certain Techniques Used in Developing a Course of Study in Science for the Horace Mann Elementary School. Craig's dissertation served as a focal point for change in the American elementary school and many of these changes can still be observed in current curricula used by elementary school teachers. Craig held that the elementary school science curriculum should deal with:

1. laws, principles, and concepts of science which are of immediate concern to the daily lives of people,
2. the health, safety, and economic aspects of science, and
3. the attitudinal dimensions of science.

Elements of Craig's philosophy continued to be expanded and developed by science educators, including Craig himself, for many years. Over the years, for example, the National Society for the Study of Education has published several Yearbooks devoted to science education. The first was published in 1932 (the Thirty-first Yearbook) and others followed in 1947 and 1960. Although science education was to become more sophisticated over the years, Craig's initial thinking can be found reflected in each of these Yearbooks. Further, Craig served as senior author of one of America's foremost science textbook series until the early 1970's. Such was his impact and reputation.

The Shame of It All

Regardless of the impact made by Craig and others over the years, problems continued to plague science education. Although elementary school science should have been more attuned to the true cultural role of science, teachers walked into their classrooms across the nation, closed the classroom doors behind them, and proceeded to prostitute the very pedagogy which permitted

their employment in the first place - a general education for all children. The science textbook became a reader and, where science activity existed, it existed largely for the sake of activity itself without any real concurrent inductive reasoning taking place. The entire premise for science in school was somehow overlooked by poorly trained administrators, inept teachers, and economically oriented textbook publishers (most of which were completely unwilling to try and change the status quo). Science educators themselves failed to understand the realities of science and how children learn and, therefore, teacher training was only marginally effective as a stimulus for effective teaching.

Thus, for many years, elementary school children were short-changed and exposed only to a descriptive, deductive approach to science - and in some schools (and it continues even today) science was ignored completely. The very nature of science provides one of the most motivating of all tools available to the teacher and for decades educators were missing the opportunity to "turn kids on" to true intellectual development. We heard about the pedagogy of critical thinking and experiential learning but "fumbled the ball" at the classroom door.

The Spectre of Sputnik

On October 4, 1957 the Russian government pushed a satellite into orbit above the earth. The accomplishment of Sputnik instantaneously created chaos in political, scientific, and education circles. The prestige of the United States, at least in the minds of many leaders, was on the line. The accusation was made, immediately following Sputnik, that the schools in the United States were deficient in the teaching of science and mathematics (although, as J. Murray Lee[8] points out, when U. S. astronauts walked on the moon, no one rose up to give credit to the schools of the nation).

In any event, the Sputnik episode resulted in a deluge of strategies for improving science education - and other areas of the education system as well. The year following Sputnik saw the passage of the National Defense Education Act (NDEA). The NDEA was intended to help every American develop his skills and competencies to the fullest. The rationale for this strategy was to help the nation develop its manpower and insure the leadership essential for the preservation of democracy.[9] In accordance with these goals was the objective of improving instruction in such content areas as science, mathematics, geography, English, and reading. Monies were made available via the NDEA for the purchase of equipment, supplies, and instructional materials in these areas. Although many dollars did, in fact, serve to improve educational programs across the nation, much of the money was squandered with reckless abandon by school boards, administrators, and teachers who gave little thought to the educational needs of children and sound instructional programming.

Following NDEA, the Elementary and Secondary Education Act (ESEA) was passed in 1965. The ESEA covered a wide variety of education problems including the education of children from low-income families, improving school library facilities, the implementation of innovative curriculum programs, and supplementary strategies (e.g., instructional materials centers, educational TV programming, learning laboratories), educational research, and the operation of Research and Development Centers as well as Regional Educational Laboratories. In 1968, the Congressional budget for Title III of ESEA alone was $208,000,000. Such was the perceived need for the development and implementation of innovative educational projects.

In addition to NDEA and ESEA, both public and private agencies involved themselves in massive efforts to upgrade the teaching of science at both the elementary and secondary school levels. Of particular interest are the contributions of the National Science Foundation (NSF). NSF has spent hundreds of millions of dollars subsidizing curriculum projects. The "Big Three" experiential elementary science programs developed with NSF funding were Science: A Process Approach (SAPA), Elementary Science Study (ESS), and Science Curriculum Improvement Study (SCIS). Although these programs differ in content, scope, and sequence, they are similar in that each involves development of scientific processes or critical thinking skills in children. Also, there are no textbooks to read; children engage in inductive activities in which thinking and doing give rise to intellectual skills and scientific information. In effect, children model the behavior of the scientist, i.e., the children generate their own information by using the same intellectual skills that the scientist uses. However, the purpose of these programs is not to turn children into scientists, but to help children become critical thinkers and problem-solvers. In these experiential science programs the deductive, read-about-science method of textbook instruction gives way to the activity-oriented, inductive method of learning. It is unfortunate to report, however, that less than 25% of U.S. students have ever participated in any of the modern science programs.

The 1980's - The Project Synthesis Report

A recounting of the program development which occurred in the sixties and seventies suggests an encouraging and healthy outlook regarding the status of elementary science education in the United States. From a fairly uniform curriculum in the early sixties which utilized science "readers" and a deductive approach, the elementary science curriculum moved in the late seventies to a state that reflected a diversity of goals, philosophies, and types of materials. As we move through the decades of the '80's and '90's, it would seem that science education could be an exciting and profitable enterprise for every youngster.

The elementary teacher has a wealth of curricular materials at hand, i.e., the three major NSF projects (SAPA, ESS, and SCIS) with their involvement in science process or critical thinking skills, as well as the traditional textbook series still in publication. These materials vary a great deal in intended student outcomes, learning/teaching styles, format, and content, and offer the elementary teacher a variety of science education options.

Despite this wealth of resources, Project Synthesis[12], the research effort referred to in Part II of this worktext, reveals a not so encouraging picture of what is going on in the classroom of the 80's. In the words of that document:

> The typical elementary science experience of most students is at best very limited. Most often science is taught at the end of the day, if there is time, by a teacher who has little interest, experience or training to teach science. Although some limited equipment is available, it usually remains unused. The lesson will probably come from a textbook selected by a committee of teachers at the school or from teacher-prepared worksheets. It will consist of reading and memorizing some science facts related to a concept too abstract to be well understood by the students but selected because it is "in the book".

There are probably a number of reasons for this present state in science education. Project Synthesis indicates that a large number of teachers do not enjoy science and lack training in science content and skills, and in how to teach science to children. Probably as a result of the insufficient training and the ensuing insecurity, there is a heavy reliance on the textbook and thus a great deal of "reading about" science and not much "doing science".

Other obstacles to effective science education identified by Project Synthesis include a lack of time to prepare for science activities, a lack of equipment, a lack of funding to provide for equipment, and a shortage of storage space. Additionally, few elementary classroom teachers have access to science supervisors for assistance and guidance.

Current societal pressures influencing the elementary curriculum are certain special-interest groups in society. A prime example of this can be seen in the "back to basics" movement prevalent during the 70's and 80's. Although the importance of basic skills can hardly be debated, the emphasis on basic skills or survival skills often ignores the necessity of critical thinking skills and frequently relegates science to a back seat position compared to subjects such as reading, oral and written communication, and mathematics. However, this may be changing.

As this is being written, it appears that the American society is once again finding fault with science (and mathematics) education and is calling for a strengthening of these subjects in schools across the United States. Various national reports including Project Synthesis stressed the importance of adequate preparation in science and mathematics for the social, economic, and political well-being of our nation. As in the past, Congress has responded with funding and the National Science Foundation is once again offering teacher training courses and workshops. It appears that we may be on the threshold of a revitalization in science education.

In Summary - Where Have We Been and Where Are We Going?

As science education moves through the 1980's, it might be helpful to recall the history of this discipline in the United States. Spanning the nearly two centuries since the didactic literature ushered elementary science into the United States, various movements and trends in science education have come and gone. The early trend toward classroom use of books which were adapted from the didactic literature was interrupted by the European-born object teaching movement. As object teaching faded and citizens demanded new science curricula, the first modern day thoughts were given to incorporating critical thinking and problem-solving skills into elementary science education. Unfortunately, teachers were unable to implement these new curricula and soon the Nature Study movement, using object teaching and faculty psychology, was widely accepted. Following this movement, Dewey, Craig and others called for the incorporation of intellectual or critical thinking skills into elementary science education. Textbooks which emerged after Craig's dissertation, however, failed to become much more than science readers. Finally, the launching of Sputnik spurred the United States government to spend huge amounts of money on education. Some worthwhile experiential science programs were developed which were based to a large extent on helping children learn process or critical thinking skills.

The present state of elementary science education does not look promising. Youngsters receive very limited experience in science from teachers who have little expertise, interest, or training to teach science. Science equipment (when it is available) receives very little use, if any. Children are most commonly involved in reading about science, memorizing facts from a text, or completing teacher-prepared worksheets.

It is important to remember that the needs of our society often determine directions in education. Whether the educational community responds to special interest groups (such as back to basics) or to the current concern for strengthening the science curriculum, it appears accurate to conclude that future trends in elementary science education will probably be, as past trends have been, reactions to historical events and movements, or reactions to and outgrowths of preceding methods of elementary school science instruction.

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Food for Thought

Science teaches us that the universe is accessible to man's reason and that its functioning can be described by laws. This very knowledge is of immense value. For example: Fears, dread, and superstitions have been eliminated by just the knowledge that the heavenly bodies follow laws and that these bodies will repeat the past behavior invariably. Man is now the proud possessor of knowledge which enables him to view nature calmly and objectively. We breathe freely because we know that nature is not willful or capricious.

. . . An education in science prepares for citizenship in the very civilization which science has fashioned. . . . government is heavily involved with science in defense, communications, transportation, health and numerous other activities. The future citizen may be called upon even as a nonscientist to take a hand in these affairs. The citizen will have to vote on issues which involve science, and the citizen should know also what governments can do to support science. Many leaders are quite ignorant of what basic research is and how it leads to benefits for society. In particular they do not know the long road from pure science to technology.

Morris Kline - 1965

Science is the attempt to make the chaotic diversity of our sense experience correspond to a logically uniform system of thought.

Albert Einstein - 1940

PART IV

The Product Side of Science

Performance Objectives

Subsequent to your interactions with Part IV you will be expected to be able to. . .

1. . . . define scientific knowledge (product) as reflected in this section.

2. . . . define (or compare, noting important likenesses and differences) facts, laws, theories, and concepts in science.

3. . . . defend the statement that "Theories can never become laws."

4. . . . explain why theories and laws can never have an absolute truth value.

5. . . . communicate the scientific value of theories and laws. Further, be able to communicate the educational implications of theories and laws.

6. . . . identify statements of scientific information as facts, theories and/or laws.

7. . . . describe the utility (from an intellectual standpoint) of concepts in terms of their being:

   a. a means of organizing information into mental categories or "packages of descriptions and relationships".

   b. a way in which the human organism can analyze (mediate) new information in terms of what is already known about objects and events in the universe.

8. . . . describe how b. (above) is dependent on a. (above).

9. . . . explain why a broad range of accurate and fairly thorough concepts help a human being adjust to his environment.

10. . . . explain why a concept held by a human being can be accurate but incomplete.

11. . . . define or describe both inductive and deductive intellectual reasoning and compare the two forms.

12. . . . diagram and explain the inductive and deductive intellectual processes involved in concept formation and the use of concepts in mediating (processing) new information. You will be expected to use an example other than the ones used in this reading.

13. . . . identify the educational benefits of teaching for concept development.

14. . . . describe the pitfalls a teacher must guard against when inductively teaching for concepts.

15. . . . identify the criteria which help a teacher decide on whether to teach a concept inductively or deductively.

16. . . . name and describe the components of the learning cycle. Further, discuss how the learning cycle maximizes concept formation and application.

17. . . . explain why a science program totally devoted to the product side of science is an abdication of responsibility on the part of the elementary school teacher.

The Product Side of Science

Many of you who read this have experienced science in school from mostly a product standpoint. That is, in your science classes, the major component of science has been the teaching of knowledge.

Today, of course, science educators feel that knowledge is not enough - that there is more to science and children should experience science in its full dimensions. Even so, knowledge in science is important even though teachers in classrooms should not rationalize a strategy for teaching only knowledge. It is unfortunate that, when product is emphasized, this dimension of science sometimes deteriorates into the learning of facts without any regard for concepts, attitudes, or intellectual processes.

What is knowledge? Knowledge in science includes all of those data that scientists agree to be true or that knowledge that scientists have generated which allows hypotheses to be formulated and tested. The important thing to consider is that knowledge (product) is produced in empirical ways which allow man to trust the products derived. Knowledge is, then, what man perceives as empirical truth - the stepping stones to a broader understanding of the universe and its objects and events.

In general, knowledge in science might be described as a composite of facts, laws, theories, and concepts. The term data merely connotes those pieces or bits of information that are empirically derived and are the constituents of facts, laws, and theories. Concepts are a different matter - we would hope that they are supported by empirical data but, alas, often they are not and they become victims of ignorance and prejudice.

Fact In Science

What is fact? A fact is merely something that is observable and/or measurable and which scientists agree is true. Facts are largely based on man's faith in empirical standards - the qualities of careful observation and standard measurement.

Some examples of facts follow. Nitrogen comprises 79% of the atmosphere. The density of gold in grams per cubic centimeter is 19.3. Venus is the planet

nearest to Earth. It is a fact that light travels at a speed of 186,000 miles per second. The speed of light has been measured. Scientists agree on the critical distance subsumed by a mile or a kilometer and they also agree on the interval of time known as a second. Once instruments were available for measuring how fast light travels it became a relatively simple matter to do so. Of paramount importance is that numerous scientists are able to substantiate this finding. This is known as the scientific quality of replication. If an observation or a measurement cannot be replicated (repeated) it is mostly worthless. Of course, it might be worthy to the person who observed it but if it cannot be repeated publicly it is largely meaningless in science. To try to convince a scientist that a unique, private observation has scientific merit would be much like seeing a ghost and spending the rest of your life trying to convince your associates (or your psychiatrist) that you really did see this spectre and that it really exists.

Even though facts are important in science, they certainly are not ends in themselves. They play a much greater role in the formation of concepts or in serving as foundations for laws and theories in science. Unfortunately, in many classrooms, teachers act as though fact is a suitable end in itself. This is not a suitable approach to science with children. Facts tend to be forgotten quickly. Educational research indicates that only 35% of factual information taught to students is retained. Further, if facts cannot be related to a more important idea or used in a problem-solving situation, they are of little value to the student.

What follows is a discussion of other product components which have considerable implication for science education. The reader is asked to attempt to perceive the role fact plays in these products and to compare the intellectual value of these products to fact per se.

Laws

A law in science deals with a specific category of phenomena - it is a statement of a relationship between phenomena. This relationship appears to be invariable under the same conditions. Laws are the generalized statements of scientists which refer to particular records of scientific data which seem to indicate exact truths in science. One example would be the Law of Universal Gravitation. Another example of a law is Gregor Mendel's Law of Segregation which refers to the sorting out and reappearance of seemingly "lost" recessive characters in the offspring of hybrids.

Mendel was a genius with plants and plant breeding. He noted, for example, that when he crossed short peas with tall peas that all of the offspring were tall. Thus, the short trait was apparently lost! However, when two hybrid offspring were crossed, the short (recessive) character reappeared in a ratio of 1 short to 3 tall. He found that one-fourth of the plants were pure tall, one-half were hybrid tall, and the remaining one-fourth pure short. Other traits in other hybrid crosses reacted in this same manner or ratio. This sorting out of genetic characters and their reappearance Mendel termed segregation. The principle involved became the Law of Segregation. Scientists have data from thousands of experiments that bear this out. Thus, we have a law which states something about the happenings in nature. We put a high degree of trust in the law even though we cannot say that this will happen ever on end! The same holds true for the laws of physics or the other laws of biology. They fit the picture we have of the universe until something comes along to modify this picture.

There occasionally comes a time when a discovery occurs in science that causes a law to be changed. Such was the case with the Law of Conservation of Matter. This law, simply put, stated that matter could neither be created nor destroyed. In the 1930's and 40's, this law was learned most carefully in high school and its "truth" faithfully accepted. Then came nuclear fission. We learned that matter can be transformed into immense amounts of energy, $E = MC^2$. We now, of course, do not accept the Law of Conservation of Matter as stated above. Physicists do believe, however, that mass is universally conserved as a property of matter and energy combined. The law was modified to accommodate this new discovery.

We can see that laws are principles or generalizations relating to the constants or regularities of happenings in the universe. A law will allow us to predict what will happen under certain circumstances in the environment. Laws are extremely valuable because of the data that support them. However, they are inductively derived and no inductive conclusion can have an absolute truth value because new data may eventually be found which will alter the conclusion and necessitate a new principle or generalization.

Theories

A theory is a generalized statement which acts as an explanation for large numbers of related facts, occurrences, or other phenomena in nature. Theories result as an observer views the universe and perceives many different data that seem to have a relationship to each other. The theories are the resultant statements which explain these relationships. Theories are, of course, inductively derived.

Theories have come and gone in science down through the ages. Some have persisted and some have failed to meet the test of time and further investigation as they were constructed on weak logic foundations. An excellent example of a poor theory was Lamarck's theory of evolution proposed in 1809. Lamarck attempted to explain evolution on the basis of the idea that changes in an individual could be brought about by influences in its environment and that these could be inherited. Lamarck's theory explained, for example, that giraffes developed long necks by stretching them for food, generation after generation. Today we know that this could not be the case. The findings of genetic evolution just do not support the theory.

The Lamarckian theory of evolution changed many years ago due to the observations made by Charles Darwin who took a world cruise on the H. M. S. Beagle. Darwin's observations on this voyage plus careful analysis of data afterwards resulted in a new theory of evolution, one which rocked the very foundations of the scientific community and one, by the way, which remains virtually unchallenged in the scientific community today. Simply, Darwin's theory was based on the idea of natural selection within breeding populations of organisms. The known facts of genetics, heredity, and adaptation bear out his thinking.

Theories act as intellectual models for viewing the nature of the universe (or a portion of the universe). These models provide a basis for scientific research. They pose a means of asking questions of the environment. Say, for example, that Lamarck's theory of evolution had received wide acceptance in the scientific community. Subsequent research into evolution would have been based on hypotheses related to that theory. Of course, eventually, scientists would have realized (and did) that Lamarck's theory (model) was unsound. A good

theory tends to be substantiated by research findings. And, this is the case with Darwinian evolution, an entirely different theoretical model.

Theories, like any other scientific model, do not have absolute truth value. We find certain exceptions to many theoretical models in science. Such is the case with the cell theory in biology and the theory of population dynamics in ecology. Even though these theories are not absolutes concerning the environment, they still serve as extremely valuable models for viewing the universe. We know, for example, that the germ theory of disease, developed by Pasteur in the 19th Century, is not 100% valid. Yet, it was a major scientific breakthrough at the time and, today, a century later, the germ theory of disease is an accepted model in research. Countless millions of human beings and domestic plants and animals owe their lives to a man who took time to view the universe with a different perspective.

Because the purpose of a theory is to explain a set of related phenomena, it can never become a law. Theories will remain theories forever, either being tested and receiving more credibility if evidence supports them or being possibly refuted if evidence contrary to the theory is unearthed. Laws, also, should not be confused with theories. The purpose of a law is to state (not explain) relationships between similar sets of phenomena. Laws may be modified because of new evidence and are not absolute because they are inductively derived. For a more indepth discussion of the differences between theories and laws, you will find the following reference helpful.

Horner, Jack and Rubba, Peter. "The Laws are Mature Theories Fable." The Science Teacher, Vol. 46, No. 2 (February, 1979).

A discussion of the reasons why there is no absolute truth in the discipline of science can be found in the following article.

Horner, Jack and Rubba, Peter. "The Myth of Absolute Truth." The Science Teacher, Vol. 45, No. 1 (January, 1978).

Concepts

A very useful component of knowledge, particularly in science education, is the concept. Although many educational variations exist for definitions of concepts, an attempt will be made to keep the definition here as simple as possible. Let us refer to a concept as the mental image one has of an object or an event or the relationships that exist between objects and/or events. Some examples of scientific concepts are: "All matter is made up of atoms." "Celestial bodies move in predictable paths." "Living things are affected by their environment."

Of prime importance is that a person's concept is his own - a private mental image generated from data fed into the intellect. This means that no one can speak or hear a concept! One can only communicate using language symbols to attempt to interpret a concept to another human being. Whether the human being subjected to the language input produces an appropriate concept is dependent on many factors.

One of these factors is the ability of the teacher and the learner to communicate effectively. Because concepts in science education are so terribly important, it becomes evident that the use of language in communicating concepts

may be one of the poorest means of developing conceptual ideas in the minds of human beings. The potential for error is tremendous and this is one reason why we cannot refer to concepts as always being empirically derived. Indeed, they may be anything but empirical!

A person's concept of a portion of his environment is tempered by and a result of his background of experiences and the evidence at his disposal. For example, a person with training in entomology certainly conceptualizes insects in a far different manner than a person with no training with respect to insects. The entomologist visualizes insects as a facet of the animal kingdom, classifiable, and of economic importance. The person with no training probably perceives many arthropods which are not insects as insects, sees no orderly manner in their classification, and relates them only to his own experiences, pleasant or otherwise.

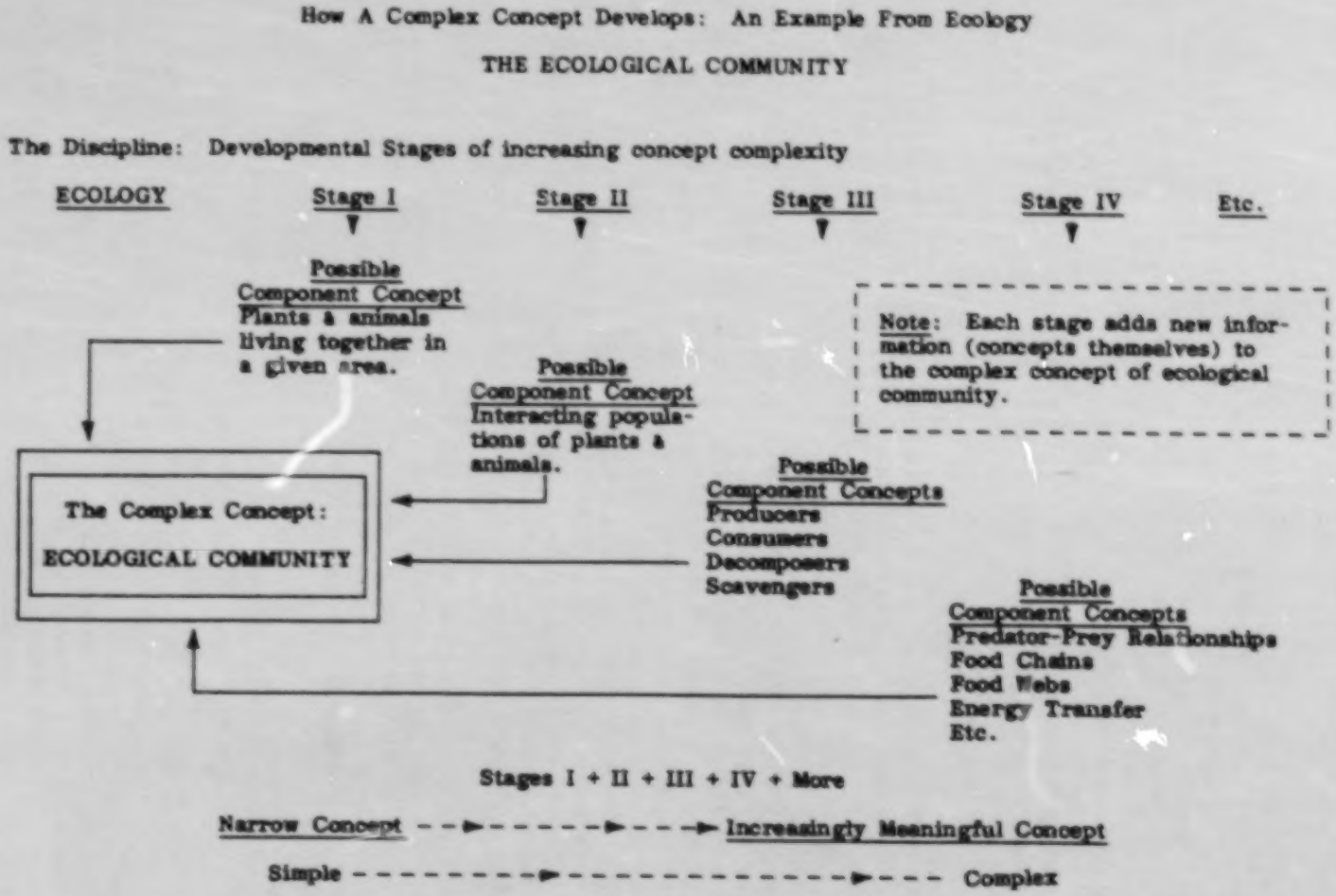
It is obvious, then, that concepts can be erroneous - or correct but limited or incomplete. The educational implications here are tremendous. If teachers select the wrong information to use to teach for concepts, the likelihood of erroneous concepts being formed is maximized. If a teacher selects a narrow array of activities to teach for a particular concept, students will probably form limited (incomplete) concepts.

An example of conceptual development might be beneficial and one can be found on the next page. Every intellectual discipline has a certain, organized structure to its information. This structure facilitates the understanding of the discipline and is often called the substantive structure of knowledge. In the science of ecology, for example, the "community concept" has, for many years, been a fundamental, rather complex concept used in the interpretation of ecological phenomena. In turn, the community concept itself is one with many bits and pieces of information impinging on it. Needless to say, the more knowledge a person has involved in his concept of "community", the more effective, meaningful and powerful the concept will be intellectually. In the presentation on the following page, we begin with a person who has either no ecological community concept or a very narrow one (although he may have a well-organized cultural community concept). Over time, this person's concept is broadened by the addition of new and unique ideas concerning community structure and interaction. This visual presentation, by no means, attempts to fully describe the variables operating in this scientific concept but it does show how a concept can grow by the addition of new information. It also helps one see how some of the inherent knowledge in the concept might be organized.

Concepts are extremely useful in dealing with one's environment. They help the individual cope with the universe in a logical and rational manner. An example here might prove helpful. Let us reflect on the usefulness of a correct and fairly thorough concept of "science" itself. The human being with an erroneous concept of science will often give to science almost omnipotent powers - he will perceive science in an altruistic manner - he will see science as being synonymous with technology - he will see the scientist in a context which is almost totally foreign to the human one in which the scientist logically belongs. All of the above conceptual positions are faulty and could prove ruinous to any large population of human beings holding tenaciously to these ideas. The value of a correct concept concerning science and the scientist is important to each human being. It permits the individual to cope with science and society - as well as with his/her own social responsibilities - in a rational and productive manner rather than in a debilitating fashion.

How A Complex Concept Develops: An Example From Ecology

THE ECOLOGICAL COMMUNITY



Correct and usable concepts also help a human being adjust to his environment. Concepts are, in fact, means by which human beings organize knowledge into useful mental categories or "packages of descriptions and relationships". They also provide a basis for the logical mediation and interpretation of new information as perceived by the individual.

Some comments regarding mediation may help to understand this process. As new data or experiences are brought into the mental patterns of the individual, they are analyzed and interpreted in light of what is already know about the objects and events of the universe. That is, available concepts are used to determine if a reasonable interpretation can be made of the new information. If the new data are seen as being related to the already held concept, the data are interpreted (mediated) with the original concept and it is revised and/or expanded to account for this new data. If a concept is not available which allows for the interpretation of these data, a new concept must be generated or the information remains uninterpreted. If data cannot be handled in some logical manner, they remain as a discrepant event to the observer. This process of mediation is similar to the assimilation and accommodation principles postulated by Piaget.

One can see, then, that conceptual development is of critical importance to the human organism if he is to be able to continually cope with all facets of his environment. And, teachers are responsible for much of the conceptual growth of human beings.

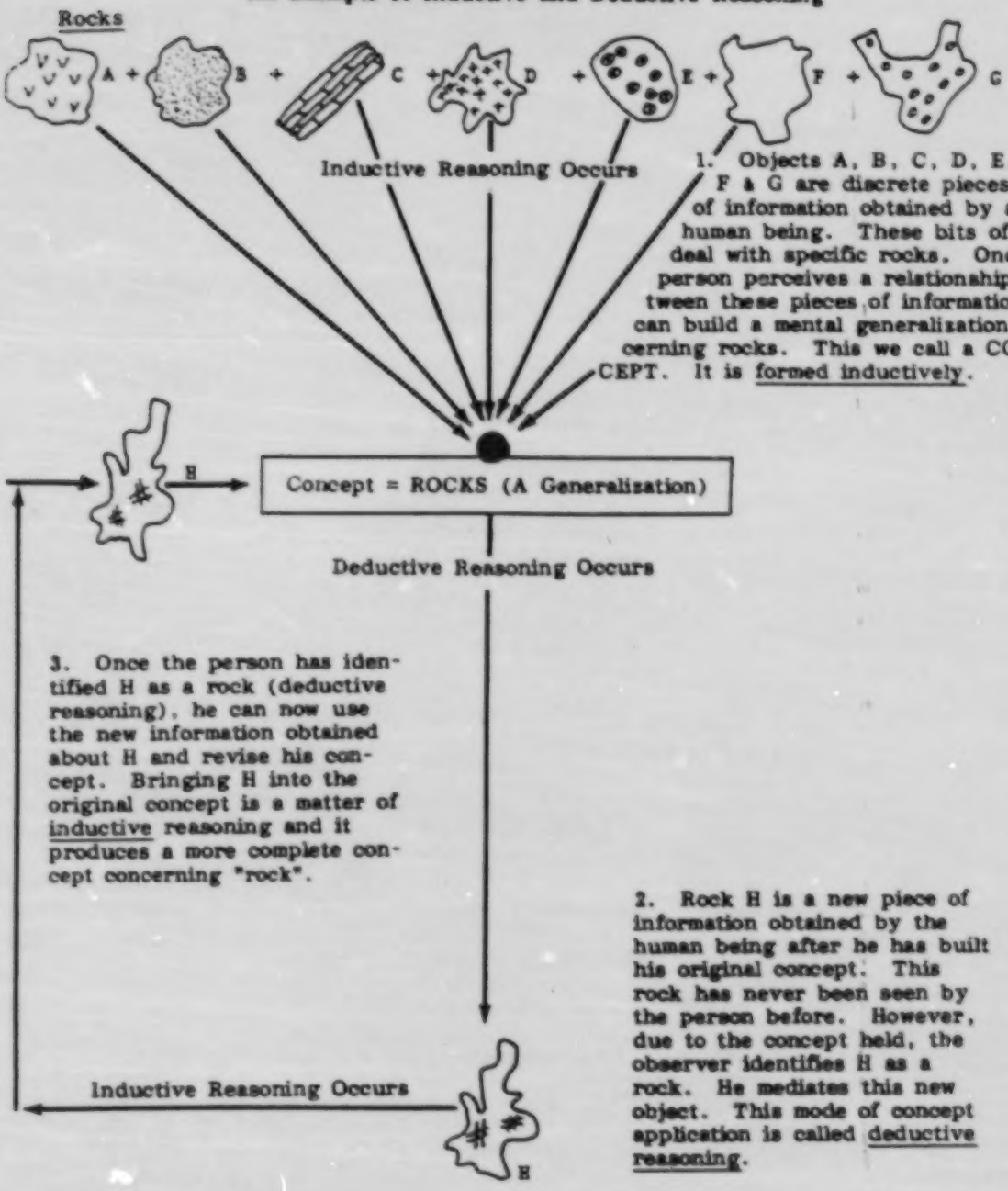
One of the common complaints among teachers centers on the quality of concepts held by students in their charge. Students just do not understand this - or that - or the other thing! Of course it's usually the former teacher's fault unless the child is a kindergartner and then the fault is the miserable experiential background provided by the parents! A rational look at these complaints points a finger of suspicion at the school itself and no teacher can avoid some responsibility for conceptual development in children. The school itself is organized in a manner which tends to force poor conceptual development in some areas. Teachers are likewise prone to use language symbols to the almost total exclusion of other methods in the development of conceptual ideas. This, of course, is a poor means of imparting accurate and thorough concepts.

Concepts are largely formed by the human intellect via inductive reasoning. Induction is a process whereby the person will pick up an assortment of separate pieces of information and put them together in some manner which makes them meaningful to the viewer. The individual generates a mental image which alludes to the relationships between these pieces of information. Of course, there has to be some connection between the bits of information - at least in the mind of the viewer. At any rate, this mental image is what we call the concept. Any new piece of pertinent information perceived by the person holding the concept can force a revision or expansion of the concept to make it even more meaningful.

Similarly, people use or apply their concepts deductively. Deduction refers to the process whereby the intellect goes from the general (the concept) to the specific from a reasoning standpoint. A simple example would help here. All human beings have a concept of human being. All of us have been getting vast quantities of data concerning the human organism almost from birth. Therefore, the inductively derived concept of human being is fairly well established. So what happens when you see a complete stranger on the street? You know almost instantly that this is another human being. You are, in fact, using your concept of a human being deductively here. Why don't you mistake this "animal"

CONCEPTUALIZATION - ROCKS

An Example of Inductive and Deductive Reasoning


Rocks
A
B
C
D
E
F
G
Inductive Reasoning Occurs
1. Objects A, B, C, D, E, F & G are discrete pieces of information obtained by a human being. These bits of data deal with specific rocks. Once a person perceives a relationship between these pieces of information he can build a mental generalization concerning rocks. This we call a CONCEPT. It is formed inductively.
H
Concept = ROCKS (A Generalization)
Deductive Reasoning Occurs
3. Once the person has identified H as a rock (deductive reasoning), he can now use the new information obtained about H and revise his concept. Bringing H into the original concept is a matter of inductive reasoning and it produces a more complete concept concerning "rock".
2. Rock H is a new piece of information obtained by the human being after he has built his original concept. This rock has never been seen by the person before. However, due to the concept held, the observer identifies H as a rock. He mediates this new object. This mode of concept application is called deductive reasoning.
Inductive Reasoning Occurs
H

for a reptile, a bird, or an amphibian? It is simply because of your excellent concept of human being and your ability to identify even strangers as human beings. You do this deductively. You mediate the stranger into your intellect. In fact, if the stranger has some unique characteristics, you may then chance to alter your concept of human being. This revision is an example of inductive reasoning.

Your attention is called to the diagram on the previous page. It visually represents the inductive process of concept formation using rocks as the concept material. It also indicates how concepts are deductively applied and inductively revised and/or expanded.

What Does This Mean For the Science Teacher?

It may seem somewhat foolish to spend so much much time here concerned with conceptual development in a reading that is supposed to identify and discuss the product side of science. It is not foolish, however, because conceptual development is so tremendously important in science education and it behooves one to understand how it takes place. A teacher who is dedicated to meaningful and effective learning realizes that sound, broad concepts have great merit. Accurate concepts, especially those inductively formulated, have great meaning to an individual. They are retained much longer than facts. They are also of great utility to the human in that they assist one in intellectually handling large numbers of related information as wholes (generalizations) rather than individual pieces of data. Concepts are also valuable because they enable an individual to mediate new experiences and adjust to them intellectually.

The implications for science education (and other aspects of education as well) in terms of concept formation are apparent - students must be given as many opportunities as possible to deal with the objects and events of science on a first hand basis in order to develop truly meaningful and accurate concepts. It should be abundantly clear that personal experiences with objects and events are much more meaningful than surrogate experiences in language symbols. Similarly, the number and/or variety of experiences (as well as their accuracy) are important. One cannot form a good concept of insect, for example, by observing one insect or by being told by a well-meaning but unknowledgeable teacher that a spider or a tick is an insect. The same holds true for any concept that is important to human beings.

The writers have made a strong case for the teaching of concepts using an inductive teaching style. To teach for concepts in this manner necessitates classroom time so that students may experience a variety of related experiences which lead to sound concept formation. Teachers must invest preparation time in order to select sound activities which are experientially oriented. Teachers are often tempted to take "the easy way out" - to tell students a concept or to have them read a textbook which states concepts. Concepts can be taught in those ways, but the learning effectiveness is much less. Students will not be the active intellectual participants in formulation of concepts they are told or read. Meaningfulness is diminished and understanding may be reduced because of the predominance of language rather than experience.

As teachers, you must make a choice as to which concepts you decide to teach inductively and which should be taught in a deductive manner. Are there criteria that might help in that decision-making process? The authors of your worktext believe there are. Some of these, in question form, are:

CRITERIA FOR TEACHING CONCEPTS INDUCTIVELY

1. Is the concept valuable from a general education perspective?
2. Can the concept be taught inductively?
3. Can the concept be taught via first hand experiences?
4. Does the concept merit maximal retention?
5. Do I want the concept to have personal meaning for my students?
6. Is the concept one that my students can transfer to other subject matter areas?
7. Will the concept have utility for my students in everyday situations?
8. Do I have knowledge of activities and/or information sources to make a valid selection of appropriate learning experiences?

What other criteria might apply? Feel free to add to this list.

Recently, science educators at the University of California at Berkeley (especially Robert Karplus) have prepared a particular inductive learning strategy called the "Learning Cycle". Originally, this was a strategy used in a NSF funded elementary science program entitled the Science Curriculum Improvement Study (see Part VII - Modern Science Programs). The Learning Cycle is a viable model for any teacher who wishes students to form concepts inductively to employ. The following explanation and example of the "Learning Cycle Inquiry Strategy" is, therefore, worthy of attention.

The Learning Cycle Inquiry Strategy*

Scenario

In Carbondale, Illinois Ms. Walters' 31 sixth graders enter the science classroom to find an array of materials and equipment on the tables. At each table is a balance, metric scale, graduated cylinder, and six cubical solids and six spherical solids. Two of each solid types are made of aluminum, two of plastic, and two of steel. One of each pair of solids is larger than the other. After taking roll, Ms. Walters begins class:

* Adapted from materials authored by Peter A. Rubba, which were published in the Illinois Science Teachers Association newsletter, the Spectrum, 1983, Vol. 9, No. 2, pp. 21-24.

It's obvious you have noticed the materials and equipment I placed on the tables. Many of you have already started on the activity for today--I saw James examining the materials and Sue weighing them.

For today's activity I want each group to explore the physical properties of the 12 regular solids that are on your table using the balance, metric scale and graduated cylinder. I have put together a worksheet that will help guide you as you collect and organize your data. Once you have completed the task I want you to examine your data for anything common to the types of solids or to the types of materials the solids are made of. Don't be afraid to reorganize your data as you search for any relationship. We'll spend about 30 minutes on this activity and then we will discuss what you found.

As the students work on the task Ms. Walters walks from group to group using supportive comments and posing questions to stimulate thought, to keep the students on task and to collect feedback on their progress. She notices that Brad and Sue have found the unique mass-to-volume ratio (which is a property of each material) on their own, and with a little prompting via questions she asks, Jane also finds the relationship. As she anticipated, however, most of the students have not recognized this relationship in their data.

After about 30 minutes, Ms. Walters begins a class discussion of the data the students collected. She uses probing questions to focus the students' attention on the constant mass-to-volume ratio which is unique to each of the three materials, irrespective of the solid's shape or size. The term "density" is introduced and operationally defined as the discussion and class period draws towards a conclusion.

At the end of the lesson summary Ms. Walters tells the class, "Tomorrow we will have an activity in which you will apply the understanding of density you developed today." In that activity Ms. Walters will ask the students to determine if any of five unknown objects, all painted the same color, are made of a different material than the other four.

A Piagetian Perspective

When Ms. Walters' 31 students approached the activity she had designed for them, they did so using their prior notions/knowledge of the properties they were to examine and the concepts they had developed through previous interactions with solid objects. The two students who independently found the unique mass-to-volume ratios, Brad and Sue, may have done so via one of two routes. First, they already may have possessed concepts which could be used to assimilate the information from the activity. In that case both students would have had their concepts broadened by the experiences provided by the activity, unless those experiences were identical to the ones the two students had previously. Or, the activity may have provided Brad and Sue with sufficient impetus to reorganize their concepts, and so, enable them to discover the mass-to-volume ratios. This is what occurred in Jane's case. Ms. Walters' interactions with Jane as she worked on the activity provided her with the direction she needed to discover the concept of density from her data.

The 29 students who did not discover the unique mass-to-volume ratios in their data were not able to do so because they did not possess the concepts into which information from the activity could be assimilated. Most probably this is because the students had few prior experiences which were germane to the concept of density. The realization that their concepts were not adequate sent these students into a state of mental disequilibrium. The disequilibrium manifested itself as an intrinsic need to move back into equilibrium; the students became more receptive to learning. The discussion Ms. Walters' led on the data provided a way for these students to order their observations, and so come back into mental equilibrium. In essence, Ms. Walters' helped these students create (accommodate) a concept associated with the concept of density as it was dealt with in the lesson.

Because the breadth of the newly created concept was limited to the experiences which lead to its creation, these students could not immediately apply it to a wide range of experiences. The activity Ms. Walters planned for the second day was designed to encourage use of the new concept and to provide further observations the students would assimilate into the new concepts thus broadening or strengthening it.

The internal mental process used by the students to try to adjust and reorganize their mental structures is called self-regulation. To encourage self-regulation students must be placed in situations where they are challenged by a problem, asked to consider tentative solutions, able to assess and evaluate the effectiveness of those solutions, and reflect upon their reasoning.

Whatever students' specific method of coping with the challenge, if the required modifications in or additions to existing concepts are NOT too great, students are likely to complete these reorganizations (self-regulate) themselves, i.e., Brad and Sue, or with a slight amount of assistance, Jane.

If the required changes in concepts are great, as they were for the majority of Ms. Walters' students, the student will need and probably seek overt help from peers, teachers, or others who they believe can suggest more appropriate reasoning. The discussion Ms. Walters held on the activity, in which the concept of density was introduced, was a direct attempt by her to encourage self-regulation among those students who needed greater degrees of help, and to continue the self-regulation process among those students for whom it had begun in the preceding activity. Such direct teaching, however, usually is not effective unless the student has had previous experiences related to the ideas (e.g., the preceding activity), or already possesses relevant concepts and can subsequently test them against his/her present observations. Still, the student must continue to get encouraging feedback from the environment to make sure that the interplay of concepts and action, an essential part of self-regulation, continues until the new concepts are firmly established, thus the need and purpose of the activity Ms. Walters designed for the second day.

The Learning Cycle

The teaching strategy Mr. Walters was using encourages self-regulation tendencies in students and discourages unquestioning acceptance of poorly understood principles and procedures. It is known as the Learning Cycle.

A Learning Cycle lesson has three phases: an exploration phase, a concept introduction phase, and a concept application phase. During exploration, the students learn through their own actions and reactions in a new situation which has been designed for that purpose by the teacher. In this phase students explore new materials and new ideas with minimal guidance or expectation of specific accomplishments. The new experience would raise questions that the students cannot answer with their existing concepts. Having made an effort that was not completely successful, the student will be ready for self-regulation and the second phase of the Learning Cycle lesson.

The second phase, concept introduction, starts with the introduction of a new concept or principle, e.g., density, that allows students to apply new concepts to the exploration's experiences. The concept may be introduced by the teacher, the textbook, a film, and/or another medium. This step, which aids in self-regulation, should always follow the exploration phase and be DIRECTLY related to the exploration activity.

In the last phase of the Learning Cycle, concept application, students apply the new concept to additional examples. A concept introduction often may be followed by more than one application activity. In some cases where the instruction is strictly sequential, the exploration for the next related concept can become a second concept application activity for the previous concept (thus, the source of the name Learning Cycle).

The application phase is necessary to extend the range of applicability of the new concept. It provides additional time and experiences to further encourage self-regulation and for stabilization of new concepts. Without a number and variety of applications, the concept's meaning will remain restricted to the examples used during concept introduction. Concept application also helps those students whose conceptual reorganization takes place more slowly.

Please note how the Learning Cycle, though based primarily on Piaget's Learning Theory, takes advantage of other learning theories also. The exploration phase permits learning by "discovery"; the concept introduction phase allows learning by repetition and practice. It must be noted, however, that recent research indicates the elimination of any one of the three phases decreases the effectiveness of the Learning Cycle. Also, teachers must not expect all students to demonstrate specific uniform accomplishments after each phase.

Epilogue

All too frequently educators imply or teachers infer that a particular instructional innovation, whether material or procedural, is a cure-all for the ills of education. While the effectiveness of the Learning Cycle is substantiated in the literature, it is not, by any means, a panacea for the problems of science education. It is, however, an instructional strategy which science teachers will want to have in their repertoire and use to its best advantage.

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As pointed out in the Learning Cycle reading, the cycle is not a panacea but it does give teachers a valuable model to follow if teaching concepts inductively is an instructional goal.

In closing . . . This, then, is the product side of science. We have briefly explored the characteristics of the facts, laws, theories, and concepts in science. Their importance cannot be underestimated. Even so, to approach science education totally from a product standpoint is to abuse and misinterpret the discipline and withhold from children one of the most important things that science has to offer - the development of critical thinking and the human intellect!

Can You Identify The Differences?

You are now ready to try your hand at discriminating among facts, laws, theories and concepts. The statements below are examples of either facts, laws or theories. They are statements excerpted from actual science textbooks. In front of each are two blanks. In the first blank, place an F if the statement is a fact, a T if the statement represents a theory or an L if it exemplifies a law. If the statement also represents a concept, place a C in the second blank. Otherwise, place no mark in the second blank.

____ ____ 1. An object placed in a liquid is pushed up with a force that equals the weight of the liquid the object displaced.

____ ____ 2. Some diseases are caused by microorganisms invading a plant or animal and upsetting the natural bodily processes.

____ ____ 3. Every mass in the universe exerts a force of attraction on every other mass.

____ ____ 4. Charges on atoms arise from the presence or absence of electrons in the outer orbit of the atom.

____ ____ 5. Matter is composed of very small particles which are in constant motion. How much motion (energy) they possess determines the physical properties of matter, e.g., solid, liquid, gas.

____ ____ 6. One British Thermal Unit (BTU) equals the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit.

____ ____ 7. The environment causes changes in an individual and these changes are passed on to its offspring. (Note: This idea is not accurate).

____ ____ 8. For any gas, the pressure will increase when temperature is increased, given that the volume remains constant.

____ ____ 9. Environmental factors, (e.g., food, space) tend to prevent living populations from either becoming very large or disappearing.

____ ____ 10. Whenever a liquid or gas speeds up, its pressure increases.

____ ____ 11. The specific gravity of gold is 19.3.

The answers to the eleven statements are listed next.

Answers to above exercise: The following statements are facts: Items 6 & 11. The following statements are theories: Items 2, 4, 5, 7 and 9. Statements 1, 3, 8 and 10 are examples of laws. You should have placed a C in front of all of these statements since each could represent a mental image that an individual can have regarding objects or events in the universe or a mental image regarding the relationships between sets of data regarding similar sets of objects and events. Students can and will develop concepts regarding facts, laws and theories.

Analyzing Concepts

The concept statements on the following page were selected from current elementary science textbooks and reprinted exactly as they appeared in those texts. You have four tasks to accomplish in regard to these concepts. You are to:

1. Decide under which Project Synthesis goal cluster(s) (Personal Needs, Societal Issues, Academic Preparation and Career Awareness) each of the concepts fit. Place the goal cluster name in the column marked Goal Cluster.

2. Decide whether you believe each concept is important for general education purposes. If you believe it is, put a check mark in front of the concept in the column labeled General Education.

3. Decide whether you believe the concept should be (or can be) taught inductively or deductively. Remember the criteria identified near the end of this section of the worktext. Place an I (inductive) or a D (deductive) before each concept in the column marked Teaching Mode.

4. Decide whether you believe the concept as written is or is not well stated, i.e., does it communicate the concept well, completely and understandably. Check only those concepts which are well-stated in the column marked Well-Stated.

The fundamental characteristic that is common to both children and science is that both are actively involved in interpreting the objects and events of the environment.

Gerald S. Craig

Concepts	Goal Cluster	General Education	Teaching Mode	Well-Stated
1. Patterns in plants.				
2. Vertebrates include fish, amphibians, reptiles, birds, and mammals.				
3. Patterns of stars in the night sky are called constellations.				
4. The stem holds up the plant and carries water from the roots to the leaves and flowers.				
5. Vaccines and antibiotics are effective against certain disease-causing germs.				
6. Yesterday, today and tomorrow exist in relation to one another.				
7. Magnets attract certain kinds of objects.				
8. There is a direct relationship between increased population, unwise use, and the depletion of natural resources.				
9. If care is not taken, household electricity can be dangerous.				
10. Living things depend basically on the capture of radiant energy by green plants.				
11. All matter is composed of atoms.				
12. Recognizing the interdependence of all organisms and the environment is the key to making the best future choices.				
13. Phases of matter.				
14. Different regions of the earth contain different biomes. Each biome is characterized by specific types of plants and animals and a particular climate.				
15. The bodies that orbit the sun differ in composition, in size, and in length of orbit.				
16. The engineer is concerned with the way things work and in building things that do work.				

PART V

The Process Side of Science

Performance Objectives

NOTE: Several of the following objectives have an asterisk (*) in front of them. These will be demonstrated specifically during a laboratory or via interpretive work done in class. The student should also be able to use these same processes on a quiz in a transfer situation.

Subsequent to your interaction with Part V you will be expected to be able to. . .

1. . . . logically defend the following statement: In order to maximize a human being's ability to think critically, education must provide that individual with operational models of specific intellectual skills and offer him/her an opportunity to use these in as many different situations as possible.

2. . . . provide a set of arguments for the incorporation of instruction in intellectual processes as part of an elementary science curriculum.

3. (*) . . . demonstrate your ability to make scientific observations. Further, you will be expected to be able to identify which senses you used in making discrete observations, to classify observations (data) as qualitative or quantitative, and to distinguish between observations and inferences.

4. . . . defend the idea that conscious mental internalization must take place for an observation to be made.

5. . . . operationally define each of the following science processes and distinguish between them: (1) observing, (2) comparing, (3) classifying, (4) inferring, (5) hypothesizing, (6) interpreting data, (7) predicting, (8) communicating graphically, (9) controlling variables, and (10) experimenting.

6. . . . cite at least two functional, cultural uses of classification other than formal scientific taxonomy.

7. . . . distinguish between the three basic types of classification schemes, i.e., multistage, binary, and serial ordering.

8. . . . defend the basic assumption that classification schemes are arbitrary, i.e., they depend largely on a person's perspective of his/her universe for immediate needs).

9. (*) . . . (a) formulate and defend an alternate and logical classification scheme for a set of previously classified objects, and (b) formulate and defend a classification system for a new set of objects.

10. (*) . . . demonstrate the ability to transfer science processes to new and unique situations.

11. . . . explain how the inferring process is related to a person's perception of the environment as well as the knowledge he/she holds concerning the environment.

12. (*) . . . prepare logical inferences based on observations of physical phenomena.

13. (*) . . . write increasingly accurate inferences based on the acquisition of new information.

14. (*) . . . write logical hypotheses which are consistent with the scientific rules of hypothesizing.

15. (*) . . . produce testable, written hypotheses based on observations of physical phenomena.

16. . . . explain why the hypothesis serves as a focal point of scientific research.

17. (*) . . . prepare a generalization based on an interpretation of a set of recorded data.

18. (*) . . . transfer descriptive and/or tabular data to a graph, correctly applying the basic rules of graphing to the task.

19. . . . distinguish between the function of a bar graph and a coordinate graph.

20. (*) . . . produce a logical, written conclusion and inferences based on ecological data.

21. (*) . . . describe or identify the differences between <u>dependent</u>, <u>independent</u>, and <u>controlled</u> variables.

22. (*) . . . identify dependent, independent and controlled variables in an experiment or problem setting.

23. . . . correctly identify relationships between variables, i.e., direct, indirect (inverse) and constant relationship.

24. (*) . . . design an experiment to test a hypothesis.

25. (*) . . . demonstrate the ability to control and manipulate variables in an experimental setting so that a hypothesis can be tested.

26. (*) . . . make correct decisions regarding the validity of a hypothesis on the basis of experimental evidence.

27. . . . analyze the pendulum process activity and identify those discrete science processes used in that activity.

28. . . . define a discrepant event and discuss its role in scientific problem solving.

29. . . . identify the correct sequence of events which occur in the scientific solution of a problem, e.g., the pendulum activities.

30. . . . analyze any of the process models used in this chapter and describe how that activity supports the concept that science is a combination of process and product.

> An hypothesis is, strictly speaking, a proposition which is put forward for consideration, and concerning the truth or falsity of which nothing is attested until the consideration is completed. It is thus necessarily associated with doubt, but with doubt of a negative rather than a positive kind. With the doubt which consists of a suspense of judgment rather than with the doubt which consists of an inclination to disbelieve.
>
> Norman R. Campbell - 1922

The Process Side of Science

The process side of science deals specifically with the doing aspect of science - the use of intellectual skills to obtain answers sought from the universe. It makes no difference whether the process is used by a child making a simple observation of a part of his environment or an astronomer searching for evidence of celestial bodies not revealed by photographs, as long as the investigation is empirical. The simplest critical observation may yield as valuable data as the most complex experiment. In fact, the scientist must continually use observation as he experiments. Knowledge of hypothesizing and inferring may well help a student cope more successfully with many academic and daily situations that seem to demand problem solving skills. Knowledge of what constitutes a rational conclusion or a logical recommendation may influence a person's decision-making in a fruitful direction rather than a debilitating one. Herein lies one of the prime reasons for helping children achieve the skills of scientific inquiry - it may be that an ability to think critically is the most liberating phenomenon of man's culture.

Should the reader find this rational for teaching science process unacceptable, perhaps a brief commentary in terms of an anecdotal defense for process education would be appropriate. Earlier we discussed the business of inductive and deductive reasoning, themselves examples of thinking processes. In the same context, emphasis was placed on concepts and conceptualization and the argument established that legitimate concept development serves the individual by enabling him to mediate stimuli impinging on his senses from the universe around him. The entire business of inductive conceptualization is, in actuality, a highly functional form of classification. And, classification is one of the basic process components of science. Man uses certain kinds of classification skills each and every day of his life, but the most important use may well be his ability to classify and meaningfully incorporate new life experiences into his intellect, i.e., conceptualization.

If man is so proficient in the use of classification in concept formation, why should we bother to promote its inclusion in science education? But, wait, who said that man was able to maximize his classification ability automatically? Indeed, we have evidence to support the notion that he cannot! Further, we have considerable evidence to support the idea that man increases in his ability to classify when he better understands the constructs of classification itself. Education can help him do this, quickly and efficiently. If that isn't enough, we also have evidence to support the contention that man's ability to classify is increased when we specifically train him to sharpen his cognitive powers of observation and comparison. Why? Because these are basic and simple prerequisite skills necessary for effective and empirically defensible classification behavior.

Similarly, there is considerable evidence to support the assumption that, once a person has had training in a specific aspect of critical thinking, he can transfer this cognitive ability to a new dimension, particularly if the new situation appears to necessitate the same kind of thinking as that on which the training was conducted. Further, modern educators of repute firmly believe that the student can be specifically taught mechanisms for transferring critical thinking which permit him to apply his ability to a wide range of new and unique situations. For example, once a child has learned how to measure temperature of water (measurement being a scientific process), he can measure the temperature of many other substances, e.g., air, his body. When a child learns how to construct a graph and how to interpret data, he can graph data in science, math and social studies and interpret data presented in newspapers, magazines, on television, etc.

If we were to generalize a statement of paramount importance concerning the development and transfer of critical thinking skills, it would be as follows: In order to maximize a human being's ability to think critically, education must

1. teach him what the skills are, i.e., define the skill;
2. teach him how to perform them, i.e., provide an operational model of each specific process, and
3. offer him opportunity to practice (use) the skills in as many different situations as possible.

In these ways, the skills become part of the student; they are not easily forgotten and can be transferred to situations other than those used as the skill teaching vehicles.

Modern science education offers one of the most powerful vehicles available for teaching critical thinking skills. This does not mean that other disciplines lack this opportunity. Science education, however, has brought process to the forefront and has designed both simple and complex vehicles for teaching cognitive skills. Hopefully, all other disciplines will eventually provide an equally significant emphasis.

An Ending Note

The authors of this worktext view critical thinking as a desirable goal for all human beings. Critical thinking is viewed as the ability to use individual process skills or combinations of these skills in problem-solving/decision-making situations in

both school and out-of-school settings. In this chapter, you will be introduced to a variety of specific science processes--namely, observation, inferring, classifying, hypothesizing, interpreting data, predicting, communicating graphically, controlling variables and experimenting. In addition, you will have an opportunity to apply these skills in science situations. These, plus other activities provided later in this worktext, should provide you with a foundation for helping children in classrooms across the nation become better critical thinkers. Hopefully, you will approach these exercises with that idea in the forefront of your mind.

An Observation Process Model

Critical observation and the subsequent correct and careful communication of observations made are the most powerful basic intellectual tools of the scientist. Basically, observation is a process of using one or more of the five senses to obtain information about objects or events. Observation and communication skills are used in a wide variety of ways in science. Further, they are integral parts of other more sophisticated processes as well, e.g., classification and experimentation. As basic, they are to be taken seriously and you are expected to demonstrate an ability to make accurate observations and communicate these clearly to others.

Observing A Candle

For starters, we are going to ask you to observe a burning candle. You will be given a number of items including a candle and matches. Place a drop of wax on the desk surface in front of you and attach the bottom of the candle to it. Next, light the candle. If you have long hair, be very careful to keep it away from the flame.

In the space below, please record ALL of the separate critical observations you can make regarding the burning candle. You should also feel free to make observations before and/or after the candle has burned.

LIST OF CRITICAL OBSERVATIONS

LIST OF CRITICAL OBSERVATIONS (Continued)

DO NOT GO ON UNTIL DIRECTED TO DO SO. THANK YOU!

Analyzing Your Observations

There will be several tasks associated with the analysis of your observations. Let's take them one at a time and see how well you have done!

Inferring--Cheating A Bit: One of the most common errors associated with students who are making scientific observations is that of slipping in a few "observations" which are really inferences. An observation in science can only be that which is available to the observer through one of his/her senses. Any interpretation of an observation goes beyond this and must be called an inference. Please go back to your original list and cross out any "observations" which are inferences.

Assessing the Senses Used: Now that you have a final list of sorts, you might find it interesting to inspect your list to determine which senses were used in making the observations. As you know, the senses were sight (S), touch (T), hearing (H), smell (O), and taste (Ta). Please code each observation on your list according to the sense used in making each observation.

Now that you have completed that task, let's determine how many times each of the senses was represented on your list. When you have completed that task please determine the percentages for each sense. Record your data below.

The Sense	Number	Percent
Sight	_____	_____
Touch	_____	_____
Hearing	_____	_____
Smell	_____	_____
Taste	_____	_____

Do you note that you used one sense more than any other? Which one? Why do you suppose this is the case?

Qualitative vs Quantitative: There remains one more analysis task for you. Observations can be either qualitative or quantitative. A qualitative observation is one which is descriptive in nature, i.e., only the senses were used to make the observation. It involves quality rather than quantity. A quantitative observation, on the other hand, involves some measurement of quantity or amount. It is more precise and usually includes a reference to a particular standard of measure, e.g., meter, gram, inch. Quantitative measurements allow for exact comparisons. Besides using instruments to measure precisely, some individuals choose to estimate or make comparisons. Although estimates and comparisons (e.g., longer than, heavier than) are still quantitative observations, they are relative and not quite as precise as specific measurements. Precise measurement should be the goal.

Go back to your original list and code each observation which is quantitative observation with a QT. Code the qualitative observations with a QL. When completed with this analysis, make certain that you have accounted for all of your observations.

How many of each kind did you have? How many qualitative (QL) ones? _____ How many quantitative (QT) ones? _____ Is there more of one than another? Why do you suppose this might be the case?

What Should the Rules Be?

You may not be an expert in observation after this one activity but you should have a pretty good idea of what's involved. Let us assume that you are responsible for teaching someone else how to make good observations. What would you teach students? What would your list of "rules" or guidelines look like?

Below, prepare a list of "Rules for Observing". Please be as thorough as possible in your analysis of this skill.

Rules For Observing

When you established rules for observation, did you consider--(1) using as wide a variety of senses as possible; (2) adding specificity by making quantitative as well as qualitative observations; (3) checking your observations with those of a fellow student so that objective rather than subjective observations are made; (4) observing before, during and after when describing a situation where a change takes place; (5) use instruments to extend your senses, e.g., microscope, balance, thermometer; (6) communicating the observation clearly and completely; and (7) discriminating between observations and inferences?

More On Observation

The ability to observe is a basic way in which man gathers information. Observation really means more than simply using one's senses, however. One must also consciously internalize the data gathered by the senses in order for the information to be meaningful and have potential for use. If you see, touch, or hear something, and do not consciously pay attention to the stimuli (i.e., register them), you have not really observed. Internalization of stimuli is somewhat related to someone hearing but not listening, or eating but not tasting a meal.

Perhaps an example might help. Without peeking, can you correctly tell your instructor the number of windows in the classroom or the color of the hair of the classmate sitting behind you? If not, why not? It may be that although you have "seen" the windows or your classmate each time you entered the room, you have not internalized what you have seen--you have not observed! Without internalization of sensory data, there is no meaning. And, without meaningful data, there are no grounds for curiosity, thought, interpretation of our environment or incentive to investigate further.

Observations Of Chewing Gum

In this second activity you will be evaluated on your observation skills and your application of observing rules. In particular, you will be observing chewing gum as it undergoes a change (chewing). In the space provided on the next page list statements of observations (qualitative and quantitative) about the gum before you chew it, during chewing, and after it has been chewed for about 5 minutes. For each qualitative statement identify the sense you used to gain the information, and for each quantitative statement identify the instrument used to extend your senses.

		Qualitative Observations (Sense)	Quantitative Observations (Instrument)
Before:	1.		1.
	2.		2.
	3.		3.
	4.		4.
	5.		5.
During:	1.		1.
	2.		2.
	3.		3.
	4.		4.
	5.		5.
After:	1.		1.
	2.		2.
	3.		3.
	4.		4.
	5.		5.

A Comparison Process Model

The world in which we live contains a wide variety of living and non-living objects and a multitude of different events. As humans observe these objects and events, they begin to notice that many of them are alike while others are very different. In other words, humans compare the things which they observe. The ability to compare critically is another intellectual process. In a hierarchical sense, comparison can only take place after observations have been made. One must first gather observational data on the individual objects or events under investigation. The mind, then, identifies the ways in which the objects/events match, i.e., similarities and the ways in which they are not similar, i.e., differences.

Humans use comparison in many daily life activities. Consider a trip to a supermarket where the consumer will compare prices, nutritional data, and preparation instructions of food products before purchasing items. A wise car buyer will usually compare gas mileage per gallon, warranty, engine size, repair costs, dealer service records, and price prior to deciding on an automobile.

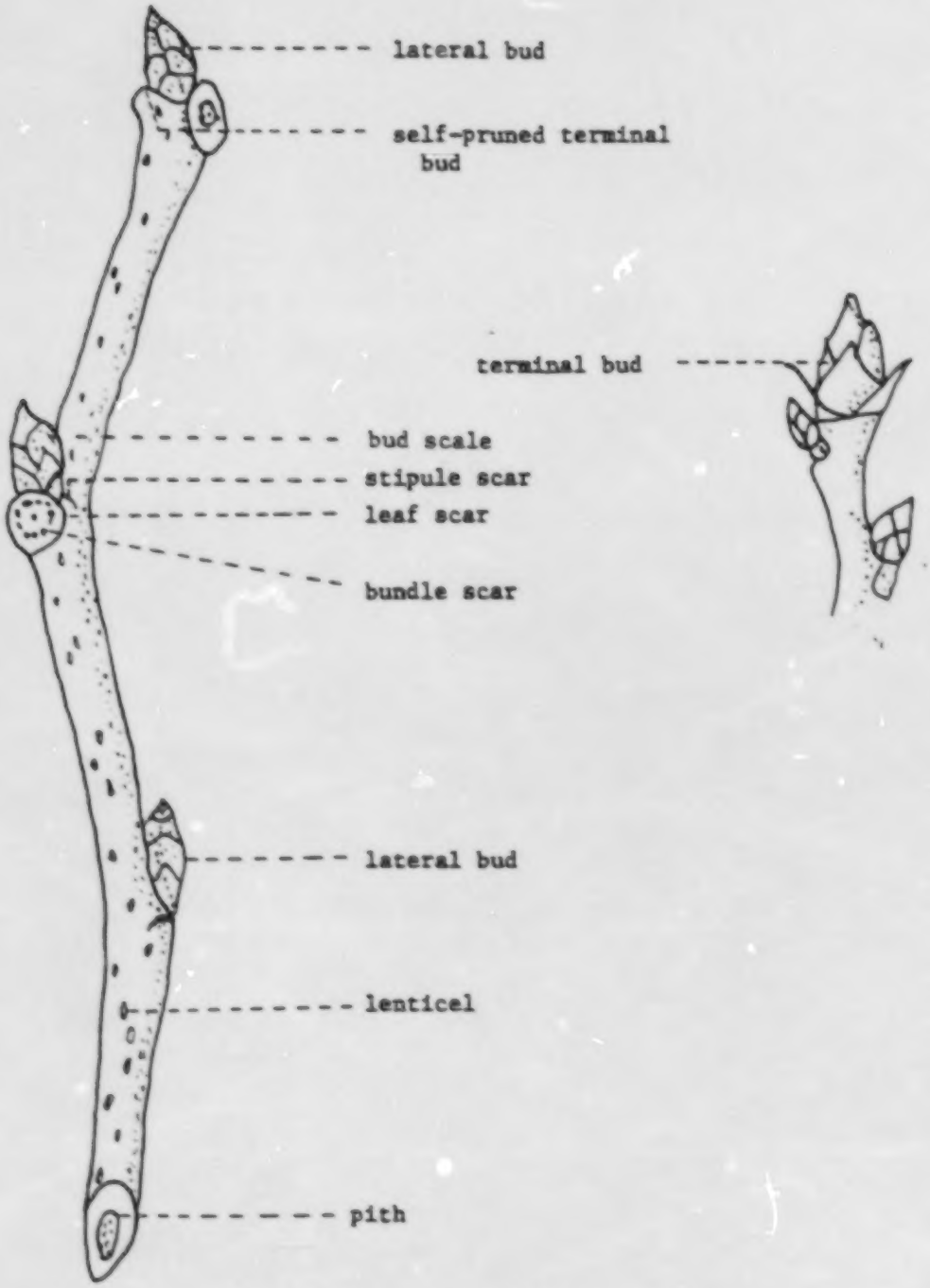
In science, comparison is an essential process. It is usually accomplished in a systematic fashion. Bacteriologists will compare cell structures of bacteria, colony color, and size as well as optimal growing conditions as part of their research. Physicists compare temperatures, pressures and volumes of gases. Comparison is also used by scientists as they classify, experiment, interpret data, or make predictions. It, like observation, is a basic science process which can be a component of more sophisticated critical thinking skills. Because many scientists and science educators consider comparison to be an inherent part of skills such as classification and experimentation, you may not find it specifically identified as a discrete process. For our purposes, however, we will spend a bit of time with comparison as a separate process.

Comparing Winter Twigs

People generally do not pay close attention to the winter twigs of deciduous trees. But, for purposes of comparison, winter twigs do offer a set of clearly observable properties (physical characteristics) which are different across tree species. Because most individuals are unfamiliar with the characteristics of winter twigs, you will find a labelled drawing of a typical winter twig on the next page. The locations and names of the major twig structures have been identified to assist you in the comparison activity. Feel free to refer to it as you progress through the activity.

On the page following the drawing of a typical winter twig, you will find accurate artistic representations of the winter twigs of two separate tree species, i.e., sycamore and an ash. Your first task is to prepare a list of the observable physical characteristics of the sycamore twig. List your observations in the space provided.

TYPICAL WINTER TWIG CHARACTERISTICS



SYCAMORE

ASH

67

SYCAMORE WINTER TWIG CHARACTERISTICS

1. EXAMPLE: Sycamore has many lenticels which look like small speckles.
2.
3.
4.
5.
6.
7.
8.
9.
10.

Stop at this point. Your instructor will hold a class discussion on the sycamore observations the class has made.

Now that you have some experience with sycamore characteristics, try your hand at observing the properties of the ash twig. List your observations in the space provided below.

ASH WINTER TWIG CHARACTERISTICS

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.

Comparison At Last!

It should have become obvious during your observing of the ash that it was both similar and different from the sycamore. Because you now have observational data on two different objects, you have the intellectual ammunition to proceed with comparison. In the spaces below, list the ways in which the twigs are similar and are different.

SYCAMORE AND ASH SIMILARITIES	SYCAMORE AND ASH DIFFERENCES
1.	1.
2.	2.
3.	3.
4.	4.
5.	5.
6.	6.
7.	7.
8.	8.
9.	9.
10.	10.

Although you could have communicated that the twigs were different at first glance, this experience should have enabled you to approach comparison systematically instead of randomly. Also, your comparisons should have been much more extensive and precise. You probably recognized more similarities than you would have initially as individuals tend to identify and communicate differences more frequently than they do likenesses. This may occur because discrepancies seem to stimulate the senses to a greater extent than do commonalities. Finally, via a discussion of the observations and comparisons, you should be starting to sort out the important twig characteristics from those which are irrelevant to the task of species description. Such abilities are the earmark of good science and are of equal value in the application of comparison to everyday tasks.

This excursion into comparison has been brief. However, subsequent activities with other scientific processes will demand your further use of comparison. More on this later!

A CLASSIFICATION MODEL

It was pointed out earlier that humans typically compare the objects and events which are observed. A step beyond this observation and comparison is the separation of these objects or events into groups that contain closely related items (those sharing of a large number of similarities). The process that humans use to accomplish this grouping is called classification. The purpose in classification is probably twofold: (1) to impose an order on the objects and events of which humans are aware and (2) to allow the overwhelming amount of knowledge which has been accumulated to be used more easily.

Since the methods of classification are man-made, one must realize that any such system is arbitrary in nature (i.e., based on or subject to individual judgment or discretion). The validity of a classification system rests on its acceptance by society in general. In scientific classification, the validity of a system depends upon the consensus, or agreement, of the scientific community. Classification takes place in other facets of life besides science. Grocery and department stores are examples of man's classification ability. So are newspaper want ads and the yellow pages. Each is based on a logic pattern with which the human mind can cope. These systems are arbitrary yet they are accepted because they are based on an orderly thinking pattern which is substantiated by the observations and comparisons humans make on any set of objects and/or events.

Most objects and/or events can be classified in more than one way as long as the classification system fits the data. For example, an entomologist might classify insects on the basis of their body structure (anatomy) whereas in agriculture, an economic entomologist would classify them as beneficial, harmful, or neutral in regards to man's domestic plants and animals. Another example: How do we classify movies? Of course, they are G, PG, R, or X. But someone else might classify them according to their subject matter, e.g., love stories, westerns, musicals science fiction. The classification scheme used is the one that fits a certain need, e.g., whether the subject matter is appropriate for children.

In summary, classification systems are created by humans to help them intellectually organize knowledge. Classification systems are arbitrary and are acceptable only if they are logical and fit the data available to the classifier. Classification systems for the same objects and/or events may vary, usually in terms of the needs of the individual(s) involved.

Learning About Attributes

You should be getting the idea that a classification system is based on the characteristics of objects (or events). Earlier we noted that insects can be classified according to whether they are harmful, beneficial, or neutral. These characteristics are called attributes. It is on the basis of these attributes that we made the decisions about how to classify insects from an economic point of view.

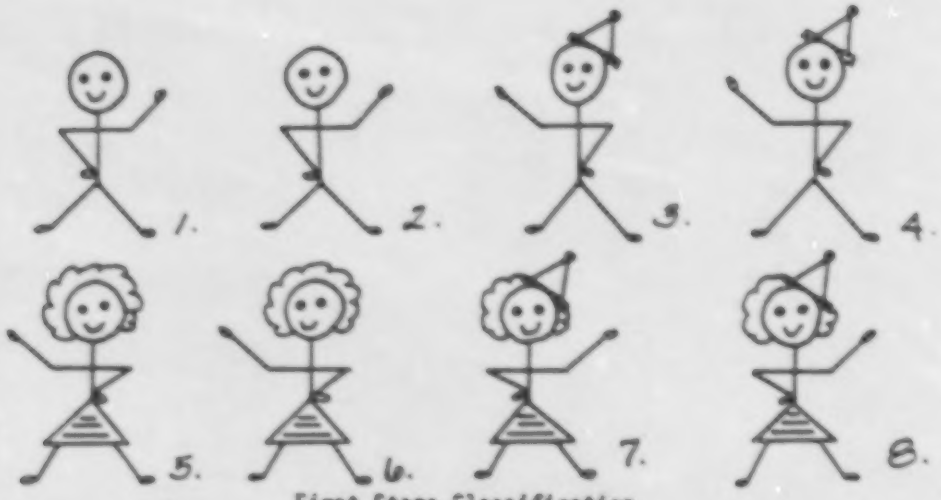
In medicine, diseases are often classified according to particular attributes. Some are classified as viral; some as bacterial. Fractures can be simple or compound. Births can be normal or breech. They can also be term or premature.

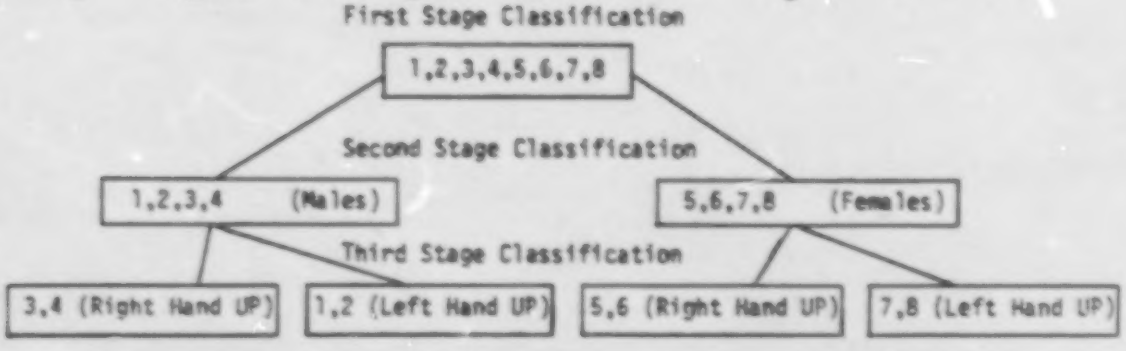
The terms used to categorize or classify diseases, fractures, or births are a function of the attributes associated with them. The attribute associated with a term birth is simply one of carrying the baby the full nine months. The attribute associated with a premature birth is a delivery of a baby which has been carried for a period of time substantially less than nine months. As in any area of science, such classifications are totally arbitrary, based on logic and a need for grouping objects or events into separate groups.

At this time we will look at some objects and identify the attributes associated with them. Let's see how well we can accomplish this.

Classifying Cheerleaders: Multistage Classification

Few people would take the time or energy to classify objects like cheerleaders. But, for our purposes here they seem like a good and fun way to begin classifying. Below, you will find eight (8) handsome, healthy, energetic cheerleaders. You will also find that they have been classified three separate times. Each time they were classified, the classification system became more refined. This particular system is referred to as a three-stage classification scheme. There could have been fewer or more stages. Please observe and compare these cheerleaders and then study how these cheerleaders have been classified.





How else might the third stage (cheerleaders) be classified?

Try your hand at reclassifying the third stage. What observable evidence do you have that will defend this new third stage?

_____ _____ _____ _____

Your evidence? _____

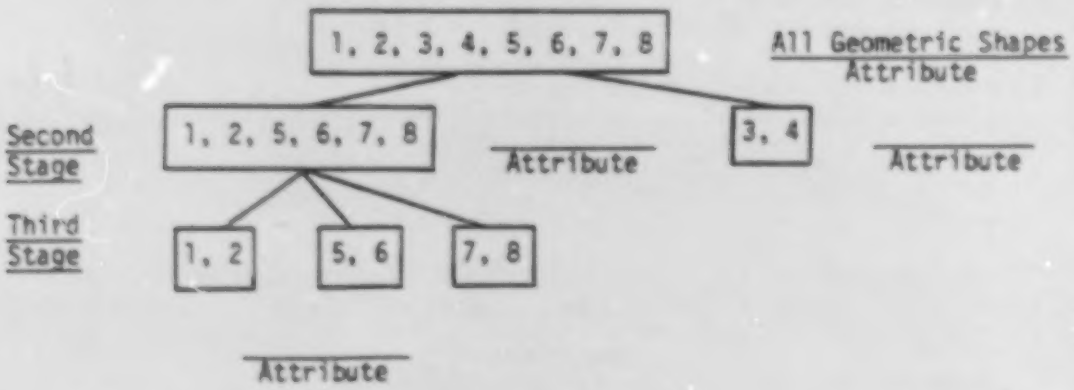
_____

A Bit More Information On Classification

Far too many people, when they are beginning to learn the basics of classification, think that the second and third stages in a three-stage classification scheme must be divided into groups that contain equal numbers of items. This was exactly the case with cheerleaders. This idea about classification is not correct, however. There are many times when the classification scheme looks quite a bit different than it did for the cheerleaders.

Let's take a look at one example of a classification scheme in which the second and third stages don't look as they did with the cheerleaders. In this particular situation we are grouping geometric shapes into a logical, but arbitrary system. What are the characteristics of the second and third stages? Write the criteria which defend the classification in the spaces provided.

First Stage Classification



Could the above classification scheme be taken to a fourth stage? Why or why not?

On To Binary Classification Schemes and Their Use

Scientists often group objects and events together via classification. However, there are many occasions when there is a need to separate objects out of the groupings into which they have been classified. One of those needs is to be able to identify a specific object. For example, beetles are put together into one order of insects (Coleoptera). They are all classified as beetles. But, what if you want to know what kind of a beetle has been preying upon your garden cucumbers? If someone isn't around to tell you what it is, you must identify (key out) and separate just this one beetle from all other beetles. If you key it out using a specific set of instructions, you are using what is called a binary classification scheme whose use is to identify specific objects.

The rules of binary classification are fairly simple. First, you find a characteristic (attribute) which is common to some of the objects in a set but not to the rest of them. This attribute divides them into two subgroups. Second, you select another attribute for each of the subgroups which will further subdivide them. If you do this often enough you will eventually have most (or all) of the objects isolated one from another. For example, a biologist might select the attribute "living or non-living" to divide rocks and minerals from plants and animals. It is important to remember that when attributes are selected, one must be sure that it divides the group so that all objects in the group fit into only one of the two subgroups.

Now, let's see how this works. On an earlier page in this chapter you will find a set of eight geometric shapes. The authors have set up a binary classification scheme for them. It follows:

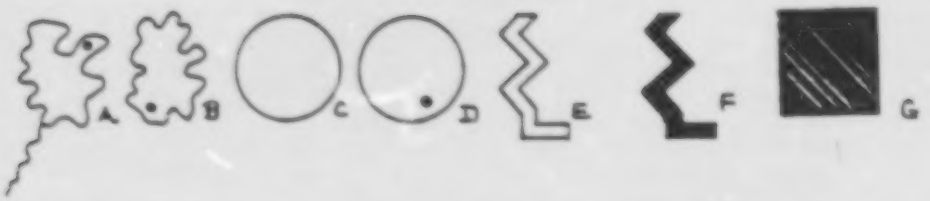
Geometric Shapes: A Key

1a.	Geo shapes with curved lines ----------	CIRCLES.
1b.	Geo shapes with straight lines ----------	go to No. 2.
2a.	Geo shapes with three sides ----------	TRIANGLE.
2b.	Geo shapes with more than three sides ----------	go to No. 3.
3a.	Geo shapes with four sides ----------	SQUARES.
3b.	Geo shapes with six sides ----------	go to No. 4.
4a.	Geo shapes with plain interior ----------	PLAIN HEXAGON.
4b.	Geo shapes with shaded interior ----------	SHADED HEXAGON.

Could this binary system have been written differently? How might it have been done differently? Would it have worked another way? What do you think?

Your Chance To Construct A Key

Below, you will find seven (7) objects. Your task is to construct a binary classification system that will permit you to key out each of these so that you will wind up with every one separated from all others. It is hard to name these objects, so you can call them A, B, C, D, E, F and G. Use as many lines below as you need. Remember what the rules are.



1a. _____.

1b. _____.

2a. _____.

2b. _____.

3a. _____.

3b. _____.

4a. _____.

4b. _____.

5a. _____.

5b. _____.

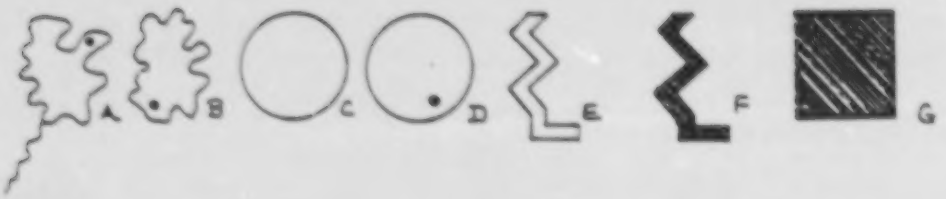
6a. _____.

6b. _____.

7a. _____.

7b. _____.

One Possible Binary Classification Scheme for Geometric Figures



1a.	Objects with shaded interiors	Go to No. 2.
1b.	Objects without shaded interiors.	Go to No. 3.
2a.	Four sided objects	G
2b.	Objects with more than four sides	F
3a.	Objects with straight lines	E
3b.	Objects with curved lines	Go to No. 4.
4a.	Objects with tail	A
4b.	Objects without tail	Go to No. 5.
5a.	Object without large dot	C
5b.	Object with large dot	Go to No. 6.
6a.	Curved lines/circle	D
6b.	Curved lines/not a circle	B

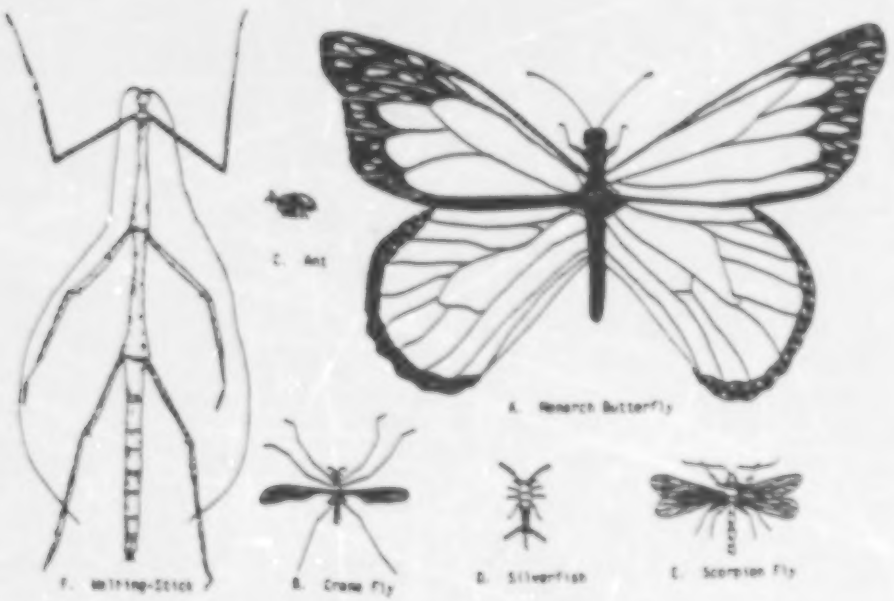
On To Serial Ordering Classification

In many instances, objects in groups can be placed in a logical order (classified) on the basis of the extent or degree to which they demonstrate a particular common attribute. This is called serial ordering classification. Objects might be classified as heaviest to lightest, longest to shortest, oldest to youngest, darkest to lightest, etc., depending on the classification purpose. Geologists classify minerals according to their degree of hardness. Biologists might classify insects according to the stages of their life cycle, e.g., egg, larva, pupa, adult. Serial ordering may well be the least complex of the four classification modes, but it is an important one. Its major rule is that one be consistent and precise with the attribute used to order the objects.

A Serial Ordering Activity*

You will find below a set of six different insects. You are to identify three different attributes by which these insects can be serially ordered. List these characteristics in the chart on the next page. Then identify an order (sequence) for all the objects in the set for each characteristic. Place the letter identifying each organism in the appropriate order in the column labelled "Serial Order". Finally, indicate the direction of that order, e.g., the smallest to largest.

Insect Specimens



* Adapted from an exercise developed by Dr. J. Ronald Gardella, Northern Kentucky University, Highland Heights, Kentucky.

Identified Attribute	Serial Order	Order Direction

A Summary

Whether one is creating a multistage system, a binary scheme or a serially ordered system, one is still classifying. Each type of classification mode has an appropriate place in science depending upon the classification need. Lastly, each of these classification types has application in everyday life activities including non-scientific occupations.

Inferring Process Model

A few years ago, a fireworks manufacturing plant blew up and burned in northeastern Illinois. This phenomenon produced some interesting inferences. One woman who lived near Chicago and heard the explosion later told newsmen that she was hearing a sonic boom at the time of the explosion. A well known Chicago TV weatherman observed, from a distance, the huge cloud that formed above the factory. He admitted on TV that he had inferred that the cloud was of meteorological origin and had failed to figure out how this one cloud had developed on such a clear day.

Such is the state of affairs with inferences. An inference is an explanation of an observation. How an observation will be interpreted (or explained) is based largely upon a person's background of experiences and the logic used in the interpretation. Both the housewife and the weatherman made inferences about the fireworks factory explosion based on their observations which were influenced by their own background of experiences--their individual frames of reference.

The weatherman was all too "human" in that he did not follow a basic rule of scientific inferring. He should have drawn as many logical inferences as possible that fit his observation. If he had done this, he could have had two or more inferences from which to choose. He might have concluded, after all, that the "cloud" could be more logically explained on the basis of a fire/explosion than on weather conditions (particularly on a day when there wasn't a cloud in the sky).

The intellectual process of inferring can be a fundamental tool of the scientist. It is used - and has been used historically - to assist the observer in producing new information. There are some classic cases where inferring has had great pay off value. Think for a moment where we might be today medically if Alexander Fleming had not inferred that the Penicillium mold he observed growing in his bacteriological plates was inhibiting the growth of bacteria. It is more than interesting to note that this same observation had been made before by

others but that it was largely ignored. Fleming's inference led to a testable hypothesis which, in turn, led to the isolation of penicillin in the 1930s.

It is critically important to differentiate between an observation and an inference. A scientific observation is empirical data brought into the mind through one of the senses. The observation is available to anyone in the right place at the right time with his/her perceptive faculties turned on. The inference, however, is much more private - it is an intellectual explanation of the observation.

You walk out of the theatre one summer night and the streets are wet. This you observe. Your inference? Of course, it rained! Which is hard data? Which is intellectual speculation?

It is also critically important to distinguish between an observation, an inference, and a prediction. A prediction is a forecast or a logical predetermination of events that have yet to occur. Scientific predictions are based on data which have been observed. They are extensions of these data. This makes scientific prediction different from forecasts made by fortunetellers or soothsayers.

Prediction, then, is highly related to the skill of observation. It is also closely allied to inferring in that predictions may also be based on inferences about the relationships between observed events, even though the inference is an explanation of the observation. For example, the TV weatherman referred to earlier might have erroneously informed his audience that it was going to rain, based on his observation of the huge cloud and his inference that it was meteorological in origin as well as his previous knowledge that certain clouds are associated with rainfall.

You will have further experience with the skill of prediction. For the moment, however, the important thing for you to be able to do is to separate observations from inferences and predictions. The following actively should help you learn to do this.

Observation?
Inference?
Prediction?

You will find a three frame cartoon on the next page. Observe the frames closely and read the statements associated with each frame. Then respond to the questions posed below the cartoon.

FRAME 1

1. Is the statement an observation, inference or prediction? _____

2. Defense for your choice: _____

_____.

3. What is the basis for the character's statement? _____

_____.

FRAME 2

1. Is the statement an observation, inference or prediction? _____

2. Defense for your choice: _____

_____.

FRAME 3

1. Is the statement (question) an observation, inference or prediction?

_____

2. Defense for your choice: _____

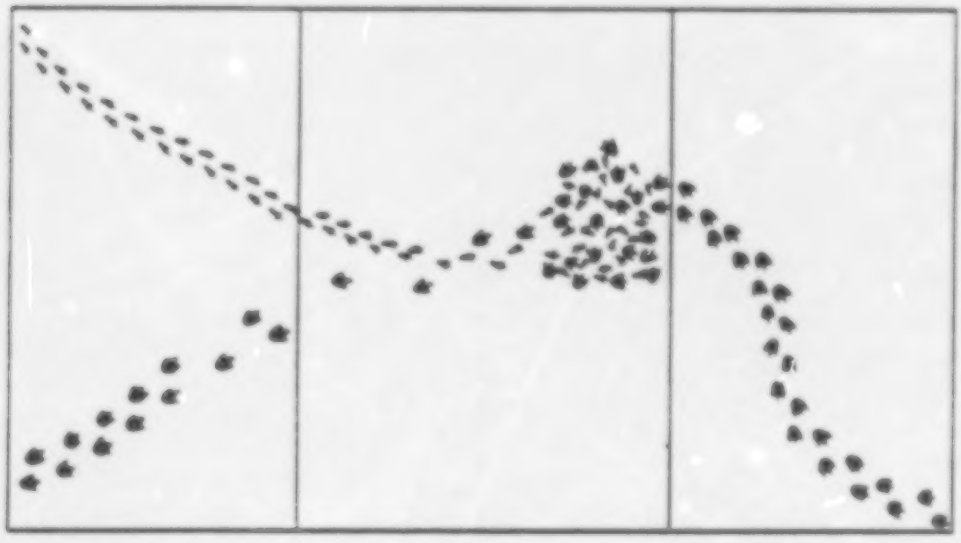
_____.

In the situation depicted in the cartoon, two experienced fishermen adamantly stated one inference and one prediction. Both of these statements turned out to be incorrect. Which, if either, of the fishermen violated any of the basic premises of science in generating the inference and/or the prediction? Why?

Creating Inferences From Observations

You will find on the next page a line drawing of fossil tracks found in a layer of sandstone in one of the western states. The line drawing has been separated into three parts, 1, 2 and 3. Your task is to make observations and inferences for each part.

Numerous observations and inferences can be made. A table for your lists is found on the following page along with an example. Make sure you separate your observations and inferences and that your inferences are logical ones from the data available to you. You do NOT need to use all spaces in the chart (or, you can add others if necessary).



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Fossil Tracks

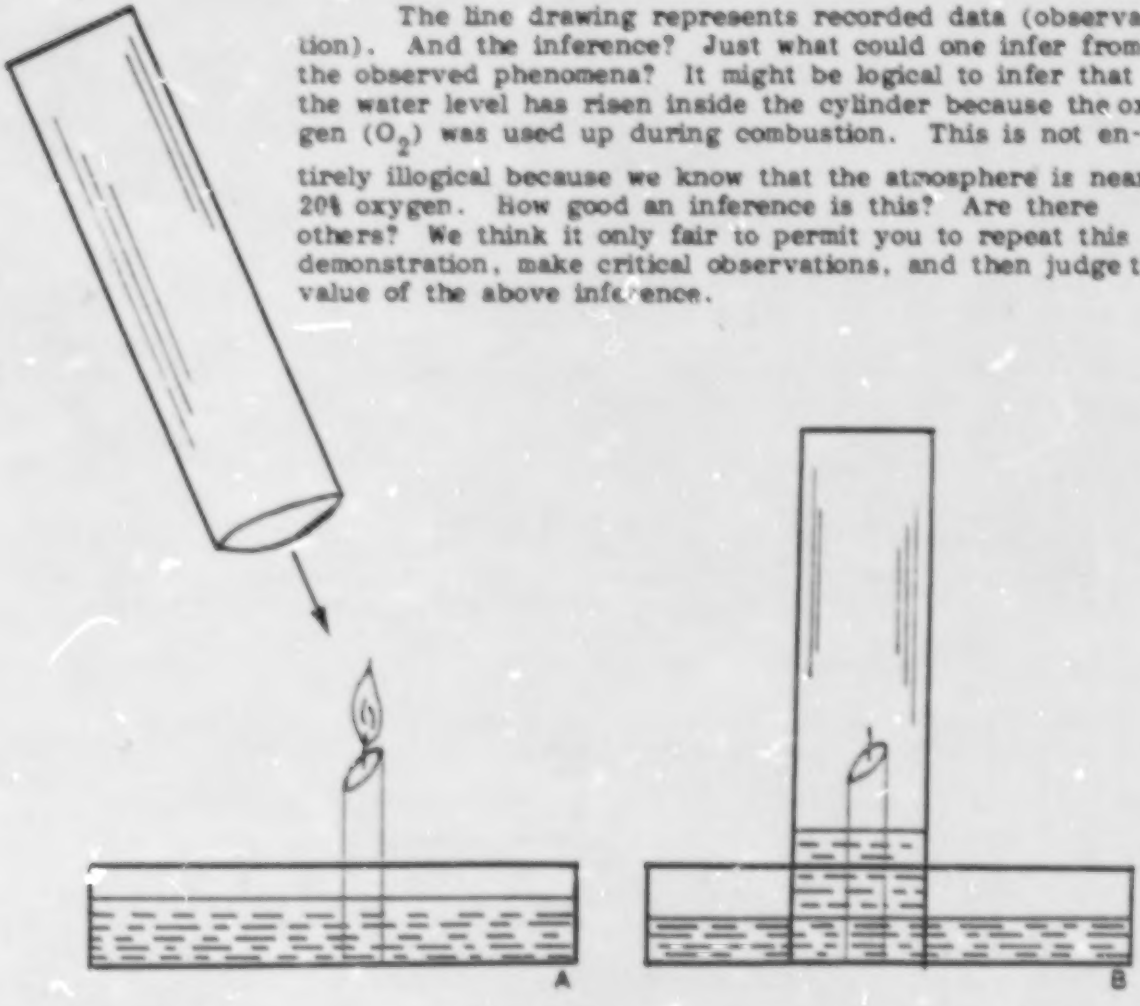
Observations	Inferences
Position 1 1. Example: Two sizes of footprints can be observed in the rock. 2. 3. 4.	Example: The footprints were made by two different animal species.
Position 2 1. 2. 3. 4.	
Position 3 1. 2. 3.	

Another Inferring Experience

On the following page you will find two line drawings. Part A represents a demonstration in progress. A glass bowl has a burning candle attached to its center. About half of the bowl is filled with water. A glass (or plastic) cylinder is about to be inverted over the candle into the water. The cylinder is closed at one end.

Part B represents the completed demonstration. The candle is no longer burning. The cylinder is about 20% filled with water. The water level has also gone down in the bowl.

The line drawing represents recorded data (observation). And the inference? Just what could one infer from the observed phenomena? It might be logical to infer that the water level has risen inside the cylinder because the oxygen (O_2) was used up during combustion. This is not entirely illogical because we know that the atmosphere is nearly 20% oxygen. How good an inference is this? Are there others? We think it only fair to permit you to repeat this demonstration, make critical observations, and then judge the value of the above inference.



Necessary materials will be provided so that you can repeat this demonstration. Please make careful observations throughout the entire process. List all discrete observations below:

On the basis of your observations, is the inference "that the water level has risen inside the cylinder because the oxygen (O_2) was used up during combustion" logical? Are there other more plausible inferences? Space has been provided below for your inference(s). If there is more than one, asterisk (*) the one that seems best.

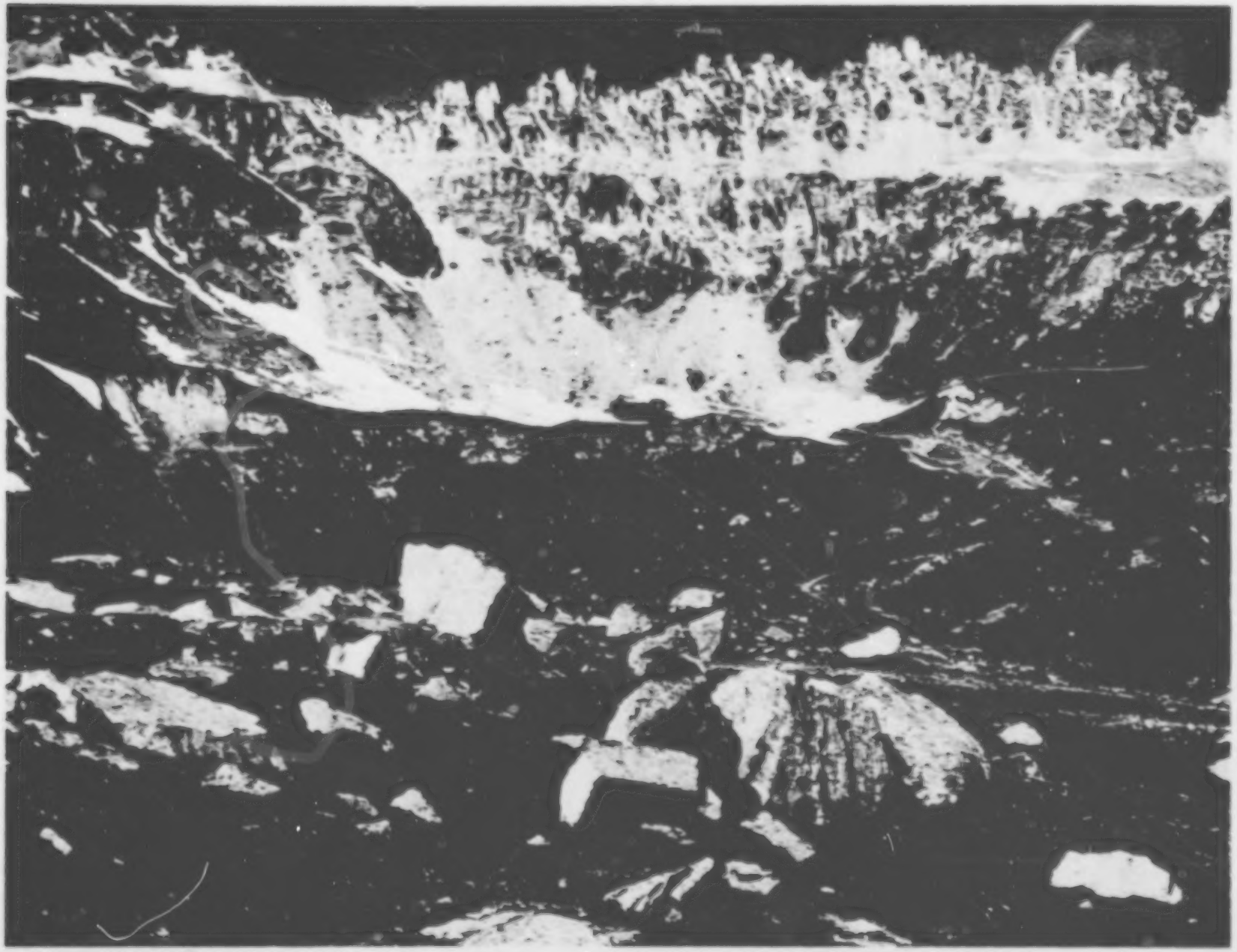
Can you think of any way to test your preferred inference? How would you go about it? We are not going to ask you to test your inference but, if you did choose to test the inference, it would become a hypothesis. Why? Because a hypothesis is a testable generalization based on observations and/or inferences about observations. More on this later!

Inferring: The Importance of Having Information

This exercise will not only help demonstrate the process dimension of inferring, it will show the value of data available to the observer, i.e., knowledge held by the observer influences the quality of inferring. We ask that you give this activity your "intellectual all".

On the following page you will find a photo. Here is some information concerning the scene at which you are looking:

> This photo was taken in August, high in the San Juan Mountains of southern Colorado. The observer is looking into a huge rock-lined amphitheater. Snow still remains on the slopes of the mountain. Huge deposits of soil and rock lie piled up at the foot of the rock walls which form the amphitheater. Immense, angular rocks lie scattered around within the amphitheater. Grass and alpine wild flowers cover the ground. If you look closely near the center of the photograph you can see a man sitting with his back to the photographer. He is seated on one of the smaller rocks found here.



Your task? Prepare an inference to account for the presence of the huge, angular rocks seen scattered about within the amphitheater. Write your inference below:

Don't be too frustrated if you feel you didn't do too well coming up with a reliable inference. We wonder how well you could do with some additional information. Here is that information:

> The San Juan Mountains have experienced long periods of glaciation. About 100,000 years ago, the North American climate was much colder than today. Snow piled up in the mountains each year and large amounts did not melt. The unmelted snow turned to ice as more snow accumulated on top of it. Over the years, thick glaciers formed and these moved down the mountains to resculpture the landscape.
>
> High on mountain tops the glacier carved huge amphitheaters out of solid rock. These amphitheaters are called cirques and are known as the birthplace of valley glaciers. Cirques are visible over much of mountainous North America and Europe.

Glacial ice will accumulate to depths of hundreds of feet inside a cirque. As it grows in depth it also moves slowly out of the cirque and down the mountain slopes. Valley glaciers are thus formed.

Your task? Prepare a new and better inference using the new knowledge now at your disposal. Write this inference below:

Could you use still more information in accounting for the huge, angular rocks seen scattered about within the cirque? Maybe your inference would be even better given additional information. Here it is:

As ice forms at the rear of a cirque, some of it becomes frozen to rock fragments on the wall of the cirque. As the glacier moves slowly out of the cirque, the ice may actually "pluck" these rock fragments out of side of the mountain and carry them along.

Rock fragments that have been moved long distances usually have a rounded appearance. Those that have traveled short distances usually have an angular appearance. As the years passed in the San Juan Mountains, the climate warmed. Eventually, the glaciers melted and disappeared from this mountain range.

Your task? Prepare your final inference using your observations of the photo and all accumulated knowledge. You should find this stage of inferring to be fairly easy. Further, you should have a high level of confidence in this, your last inference. Why?

Write this last inference below:

Do you feel more comfortable with your last inference than you did with either the first or the second? If so, why? Would it appear that a person's knowledge or concepts affect his ability to infer successfully?

In the specific problem revolving around glaciers, cirques, and angular rocks you may wonder whether it would ever be possible to test such an inference. In fact, it is very possible! How? Earth scientists attempt to interpret the past by observing present events. They travel to a point on the earth's surface where glaciation is active today and carefully observe the associated phenomena. It is a fairly simple matter to find analogies between present observations and evidence remaining from the past. Such is the case here. The earth scientist will readily tell you that understanding the present is the key to interpreting the past! This is an accepted assumption in the field of earth science.

Hypothesizing Process Model

Earlier in the chapter, you learned that if you chose to test a particular inference, that inference would really become a hypothesis. Confusing? Perhaps, but the following information and activities should help clarify your thinking and help you become more comfortable with the process of hypothesizing.

Hypotheses are widely used in all facets of science, e.g., physics, chemistry, behavioral science. A hypothesis is sometimes defined as a testable generalization based on observations and/or inferences about observations. These statements are subject to immediate or eventual testing by one or more experiments.

As one studies both of the above definitions, three key characteristics of hypotheses emerge. They are: (1) hypotheses are generalizations; (2) hypotheses must be testable; and (3) they are based on observations and/or inferences. Let's see how these characteristics might apply in a specific behavioral science situation.

Assume that you are a sixth grade teacher who is also interested in doing educational research. Your observations of sixth grade students seem to infer that they are, many times, motivated to learn for the sake of grades. You ponder this and decide to enlist the help of a number of fifth, sixth, and seventh grade teachers in conducting an experiment to test your inference. Your research hypothesis might read as follows:

> Research Hypothesis: Middle school students will perform significantly better when extrinsically motivated by grades than students who have no such external motivation for learning.

Is the above statement a generalization? If so, to whom does it generalize? Is it based on observations? Inferences? Both? Can it be tested? If so, how? On the basis of your responses to these questions, you should have determined that the sixth grade teacher's statement fits the definition of a hypothesis.

More On Hypothesizing!

When a hypothesis is stated, it tends to describe a specific relationship between factors (variables) in a given situation. Indeed, well stated hypotheses may be considered to be attempts to predict the effect that one variable has on another variable, e.g., if x increases, then y will increase. In the research hypothesis presented earlier, a relationship between one variable (school performance) and another variable (type of motivation) was stated. The teacher was attempting to predict that using extrinsic motivation would positively increase students' performance.

Critical to the task of formulating good hypotheses is the ability to identify the pertinent variables inherent in a particular situation. These pertinent variables fall into one of three types. The types are:

1. Manipulated Variable: the variable which is purposefully (deliberately) changed in a situation. Another name for the manipulated variable is the independent variable.

2. Responding Variable: the variable which may change or be affected as the result of the manipulation. A responding variable can also be called a dependent variable.

3. Controlled Variables: the variables which are purposefully held constant or stable in a situation, thereby allowing only one variable to be manipulated and its effects on the responding variable to be determined.

Hypothesizing involves examining a situation and identifying the variable which is to be manipulated (tested), the variable which responds to the manipulation and the variables which will be purposefully controlled. The hypothesis is then stated. It should contain both the manipulated variable and the responding variable as well as the relationship between the two. It is not necessary to state the controlled variables in the hypothesis, although they become very important when the experiment to test the hypothesis is designed.

The activity which follows should give you some experience in identifying the kinds of variables which are stated in hypotheses.

Identifying Variables

You will find below three hypotheses. Read them carefully and identify the manipulated variable and the responding variable within each. Lastly, describe the type of relationship which exists between each manipulated and responding variable.

Hypothesis 1:

A population density of fewer than three immature angel fish per gallon of aquarium water will result in more rapid growth of individuals in that population than will a population density of three or more fish per gallon of aquarium water.

Manipulated Variable: _____

_____

Responding Variable: _____

_____

Relationship: _____

_____

Hypothesis 2:

Greenhouse orchid plants fertilized every fourteen (14) days with a dilute solution of 20-20-20 will produce more flowers than those fertilized only once a month.

Manipulated Variable: _____

_____

Responding Variable: _____

_____

Relationship: _____

_____

Hypothesis 3:

There will be fewer occurrences of heart attacks in a group of adult females who exercise a minimum of 3 times a week (during which they maintain their pulse rates in the "target range" for a minimum of fifteen minutes) than in a group of adult females who do not exercise in this fashion.

Manipulated Variable: _____

_____

Responding Variable: _____

_____

Relationship: _____

_____

In the above activity, the hypotheses had already been written. A more difficult task is to construct a hypothesis for a particular situation. Let's try that next.

Constructing Hypotheses

Assume that you are a naturalist who is studying bumble bee reproduction. You observe that varying numbers of young bees hatch from the three equal sized underground nests you are studying. You wonder what factors might influence the hatching rate of the bumble bees. You infer that one factor might be the temperature in the nest and that another possible factor might be the number of adult bumble bees available to tend the developing larvae. Construct two hypotheses--one for each of the inferences stated above.

1. Hypothesis: _____

_____

_____

2. Hypothesis: _____

_____

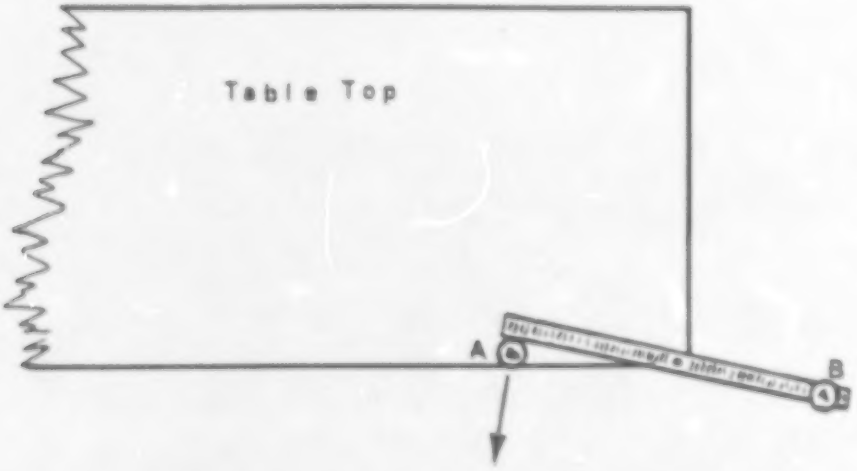
_____

Do you really know what the effect of manipulating each of the above variables will be? Not really--that is, not until you design a set of experiments which test the hypotheses you constructed.

Now we are going to put you into the real three dimensional world of hypothesizing. Follow instructions carefully!

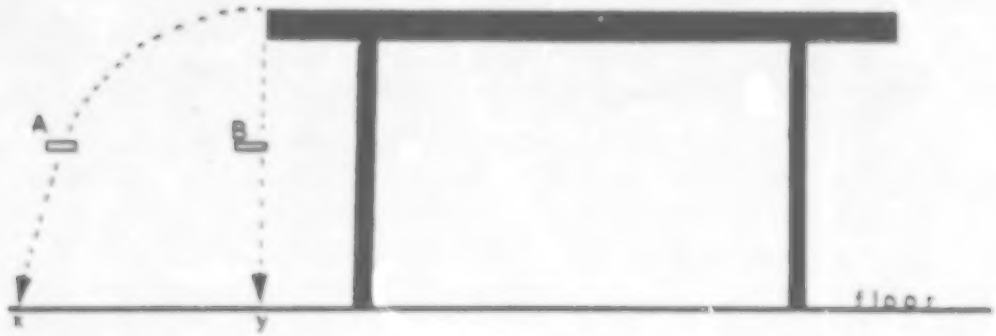
Hypothesizing In Earnest!

For this activity you will need one 30.5 cm ruler (center punched), two coins of equal denomination, an assortment of other coins, paper or cardboard and a pencil. In this activity you are going to observe the effect of gravity on falling bodies, e.g., coins. Before you can do this effectively, however, you must develop some psychomotor (manual) skills.



Using a table top, ruler, and two coins of equal denomination (e.g., 2 nickels, 2 quarters, 2 dimes) set up the demonstration as you see it in the drawing above. Place the pencil in the center punched hole so that it acts as a pivot point.

Using your middle finger, flick the ruler in such a way as to force coin A off the table and coin B off its station on the rule. This can be difficult to accomplish at first so practice until you have the technique down pat. When you have polished your technique, the results you obtain will appear to be something like the following:



Now, record your observations of the phenomenon as it relates to the "behavior" of the two coins.

Observations:

Now, try the same procedure with two identical coins of a different denomination. For example, you might use two half dollars. Carefully, observe what happens.

Does a hypothesis come to mind? One should! It should relate to a generalization concerning the phenomena you have observed. Write this hypothesis below:

Hypothesis 1:

The following represents one possible hypothesis for the above events: Objects of equal mass, whether dropped or pushed from equal heights, will hit the floor at the same time.

Is the hypothesis testable? How would you go about testing it? Think of specific ways of testing your hypothesis.

Now let's modify the situation slightly. Repeat the demonstration using coins of two very different masses, e.g., a quarter and a dime. What do you observe the results to be? Repeat the procedure a second - even a third or fourth time using different coin combinations. Was the original hypothesis a good one? Did it account for enough variables? If not, revise the original hypothesis below:

Hypothesis 2:

Is Hypothesis 2 testable? Does it follow the rules for hypothesizing? Think of specific ways of testing this hypothesis. You might, for example, want to use entirely different objects this time. In fact, test the hypothesis by using a coin and a small, flat piece of paper provided by your instructor.

The data from the above test for Hypothesis 2 should eventually lead you to revise Hypothesis 2. If your inferences are based on all possible data and if you have used good logic in forming your inference(s), you will be forced to write a third hypothesis that could be tested (but only in a more sophisticated laboratory than the one in which you are working). How would that hypothesis read?

Hypothesis 3:

It should be obvious, at this point, that hypotheses are, in fact, very special kinds of inferences about the universe. Further, they must be testable and they should relate to some generalizable principle or concept. Even though a research hypothesis may not prove itself to be correct, it still functions as a focal point of research in that it establishes the guidelines for experimentation. The hypothesis is accepted, rejected, or revised on the basis of the experimental results.

Interpreting Sunspot Data

On the next pages you will find graphs which portray biennial sunspot numbers (data) between 1800 and 1974. Sunspot data, like so many other data, help generate the scientific assumption that the happenings in the universe are mostly governed by laws and that events are not capricious and unpredictable, i.e., scientists believe that there is order in the universe.

Interpreting data involves observing known information with the expectation of determining what those data indicate. Put another way, what do the data mean, i.e., what do they tell us about events under investigation?

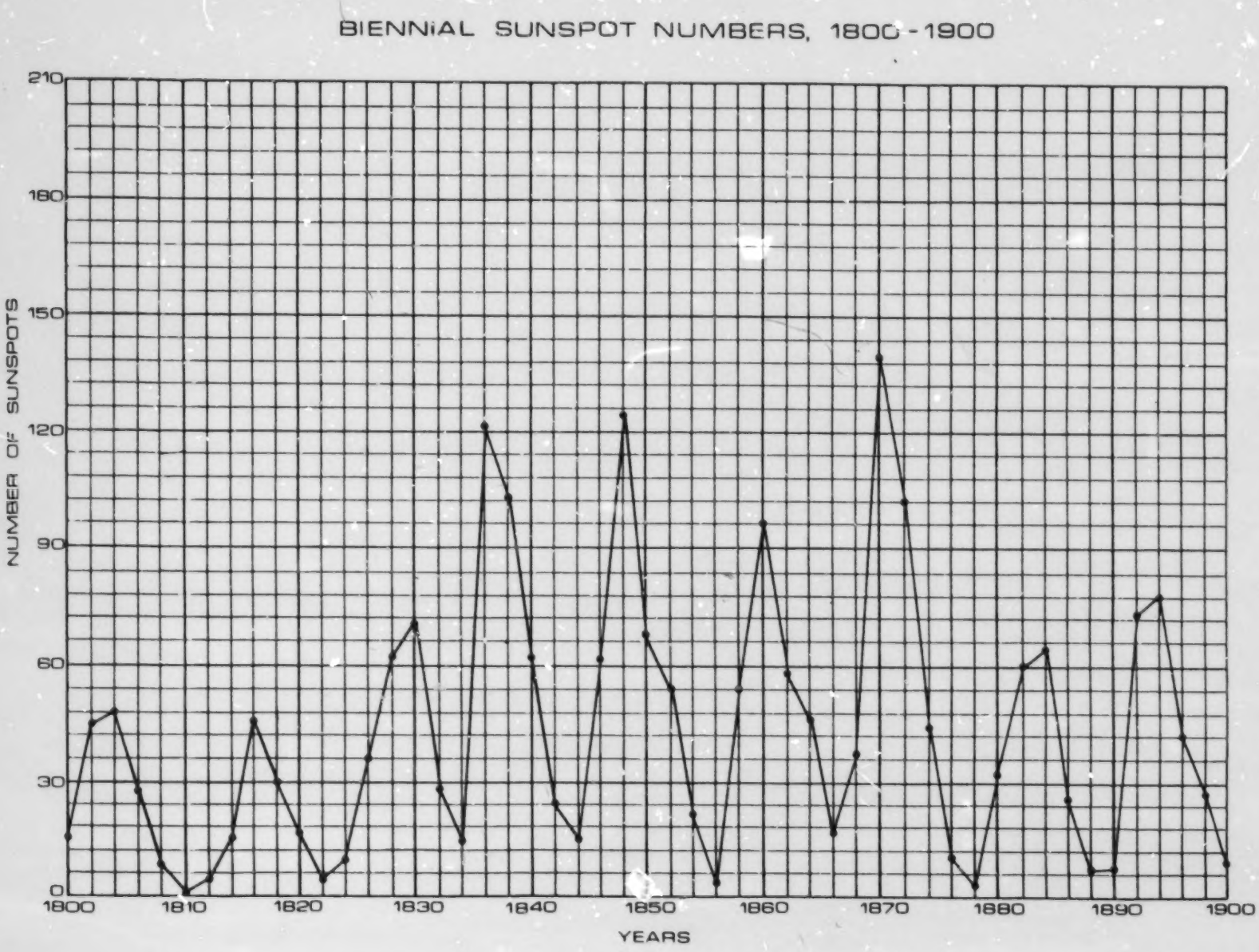
If you observe the sunspot data carefully, you should be able to see some patterns or repeated phenomena that indicate a certain orderliness in those data. If this is the case, you should be able to state a generalization (data interpretation) concerning sunspot activity between 1800 and 1974. This generalization could consist of one sentence or several. Try your hand at interpreting these sunspot data.

My interpretation of sunspot data:

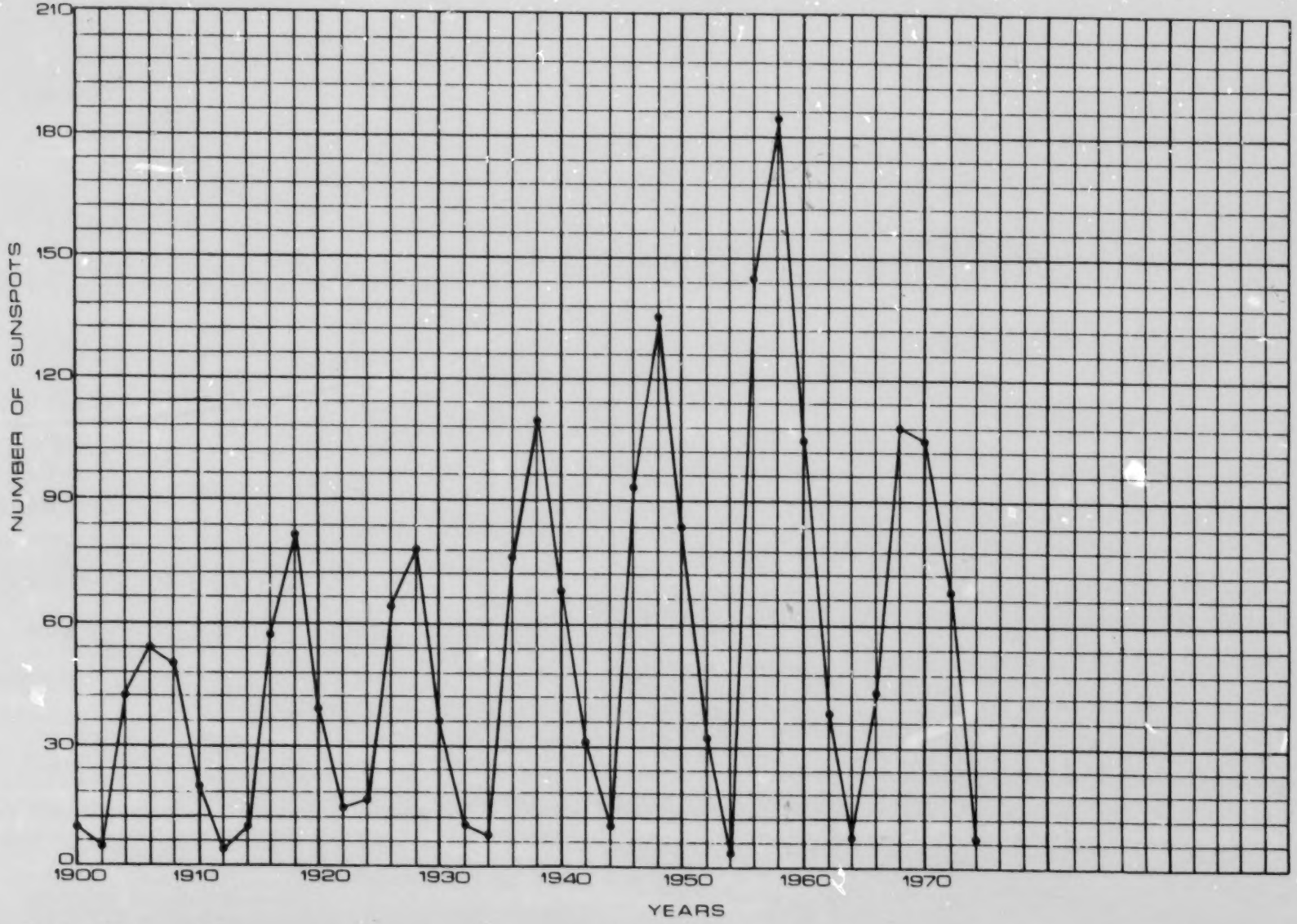
How would you go about checking the validity of your interpretation? A number of questions should help determine the validity of your generalization. Is your interpretation totally consistent with the data? Have you overgeneralized, i.e., have you written some statements that are really not supported by the data? Do others agree that your generalization is correct? It might be wise to check your interpretation against those prepared by others looking at the same data.

Predicting Future Sunspot Activity

Scientists also use data interpretation techniques to predict future events. Who in the world would be interested in predicting future sunspot activity? Lots of people! Why? There is, for example, a high correlation (relationship) between the degree of


BIENNIAL SUNSPOT NUMBERS, 1800 - 1900
NUMBER OF SUNSPOTS
210
180
150
120
90
60
30
0
1800
1810
1820
1830
1840
1850
1860
1870
1880
1890
1900
YEARS

BIENNIAL SUNSPOT NUMBERS, 1900 - 1974



sunspot activity and radio reception. C.B. radios are particularly difficult to operate normally during periods of high sunspot activity. There is also some evidence that certain animal population cycles are correlated with sunspot activity. This information would be of considerable importance to wildlife managers. Also, tree growth has been shown to be correlated (historically) with sunspot activity. Who might be interested in those data? Thus, sunspots can be of vital concern to particular elements of society and the scientific/technological community.

Do you think that there are enough data in the accompanying graphs to predict future sunspot activity? If so, how accurately do you think you could do this?

Let us assume that it is crucial for you to be able to predict sunspot activity between 1990 and 2000. What would your best scientific prediction be? Write it out below. You might also wish to pencil it right on the graph found with this activity (enough room remains on the graph paper to predict up to the year 2000).

My prediction:

Graphing - One Form of Scientific Communication

Preparing and interpreting graphs are two very important skills in the science classroom. Accurate and clear data communication is crucial in science. In fact, these skills are considered so very important by scientists and science educators that in at least one progressive science program, graphing is introduced at the second grade level.

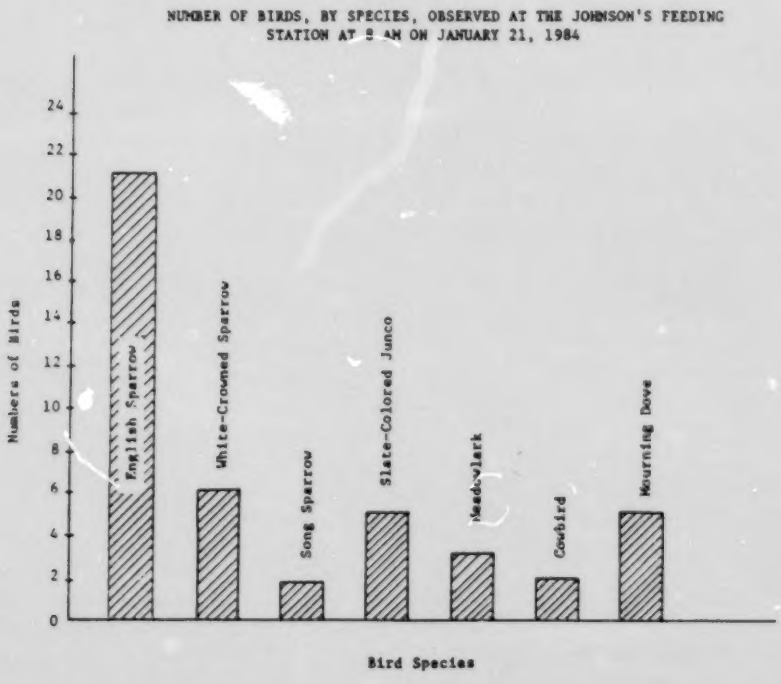
Numerous kinds of graphs exist which allow wide arrays of data to be presented. In the elementary and junior high schools, the bar graph and the coordinate graph are the two most frequently used.

The bar graph is typically used to display data which show comparisons between groups/variables. For example, let us assume that you wanted to display information about the various kinds of coins you had hoarded in your piggy bank for the last two years. You might want to count the pennies, nickels, dimes, quarters, and half dollars you had stashed away. These data could be displayed on a bar graph nicely, i.e., so many pennies, so many nickels, dimes. The denominations of the coins would be written on the horizontal axis of your graph and the numbers of coins on the vertical axis.

Other examples of data which could be displayed in the bar graph format include numbers of different kinds of injuries recorded in the Emergency Room on a particular weekend or the number of toxic waste disposal sites in each geographic region of the United States.

In this section on graphing you will find a graph concerning observations made at a bird feeding station on January 21, 1984. Note how easy it is to look at the proportion of one bird species compared to another. Here is an example of a simple comparison between groups (species of birds).

Of course, bar graphs can get very complicated and display complex sets of data. Suppose, for example, one wished to compare the numbers of birds, by species, at the feeding station on the 21st day of each major winter month, i.e., January, February, and March. How might this be done on one graph? Needless to say, such a display of data would be much more complex than the one displayed here. Yet, it could be extremely useful for a person needing to see trends in bird species during the winter months.



The coordinate or line graph is typically used to show increases and/or decreases in variables or to show change in variables over time. Here we are involved with data which can be displayed in a continuous line or set of lines. Examples might be numbers of students admitted to medical schools in the U. S. between 1940 and 1980, numbers of English sparrows observed at the Johnson's feeding station at hourly intervals on a particular day, the growth of sweet corn in centimeters from the time of germination to maturity, or the relationship between temperature and pressure observed for a particular gas.

Looking back at the graph which displays sunspot data between 1800 and 1900 will provide you with an excellent example of a coordinate graph. It depicts changes over time. Numbers of sunspots are found on the vertical axis and time (years) is found on the horizontal axis. The coordinate is the correct point on the vertical axis for the number of sunspots observed during a particular year, i.e., the point where the appropriate vertical and horizontal axes meet. Here a dot or mark of some kind is recorded. When all dots are in place, they can be interconnected with a line if this proves helpful in interpreting the graph. Such is the case with the sunspot data.

Certain rules should be followed in the preparation of a coordinate graph. They also apply to bar graphs. These are as follows:

1. The graph must have a title which adequately describes the relationship shown between the variables on the graph.

2. The horizontal axis should be labelled (this is the axis used to display the systematically changing variable, e.g., seconds, hours, weeks, years).

3. The vertical axis should be labelled (this is the axis used to display the results which are observed, e.g., numbers of English sparrows, height of sweet corn, numbers of sunspots).

4. All intervals on an axis should be equal and continuous. One cannot go from year to year on a graph and then suddenly skip ten years, for example. Similarly, the distances (intervals) between the years must be the same throughout.

5. Coordinates or data must be plotted accurately.

Recording and Interpreting Ecological Data*

It is much easier to report and interpret data in science when it is reported in an orderly, organized manner. Similarly, many situations appear to demand the use of graphically presented information. Regardless of the mode used, accurate and clear communication of data in science is critically important.

A demonstration of the need for clear, concise communication seems in order. We will use historical ecological data for this purpose.

* Adapted from H. R. Hungerford and R. A. Litherland. Process Modules for Investigating Environmental Problems. Published by the authors, 1975.

Significant fluctuations in the deer population occurred on Arizona's Kaibab Plateau between 1905 and 1938. These population figures represent one of the classic case studies in North American wildlife management. In 1907 there were approximately 6,000 deer on the plateau. By 1910 they had increased in number to 10,000 and by 1915 the population had risen to 25,000. The year 1920 saw approximately 56,000 deer present and by 1923 the population had soared to 100,000. 1925 saw the population decrease to 85,000 and by 1930 it had fallen to 30,000. In 1935 there were but 14,000 deer present and in 1938 the population had been reduced to 9,000 animals.

Now let's present these same data in a different format. They follow:

Deer Population on the Kaibab Plateau from 1907 to 1938

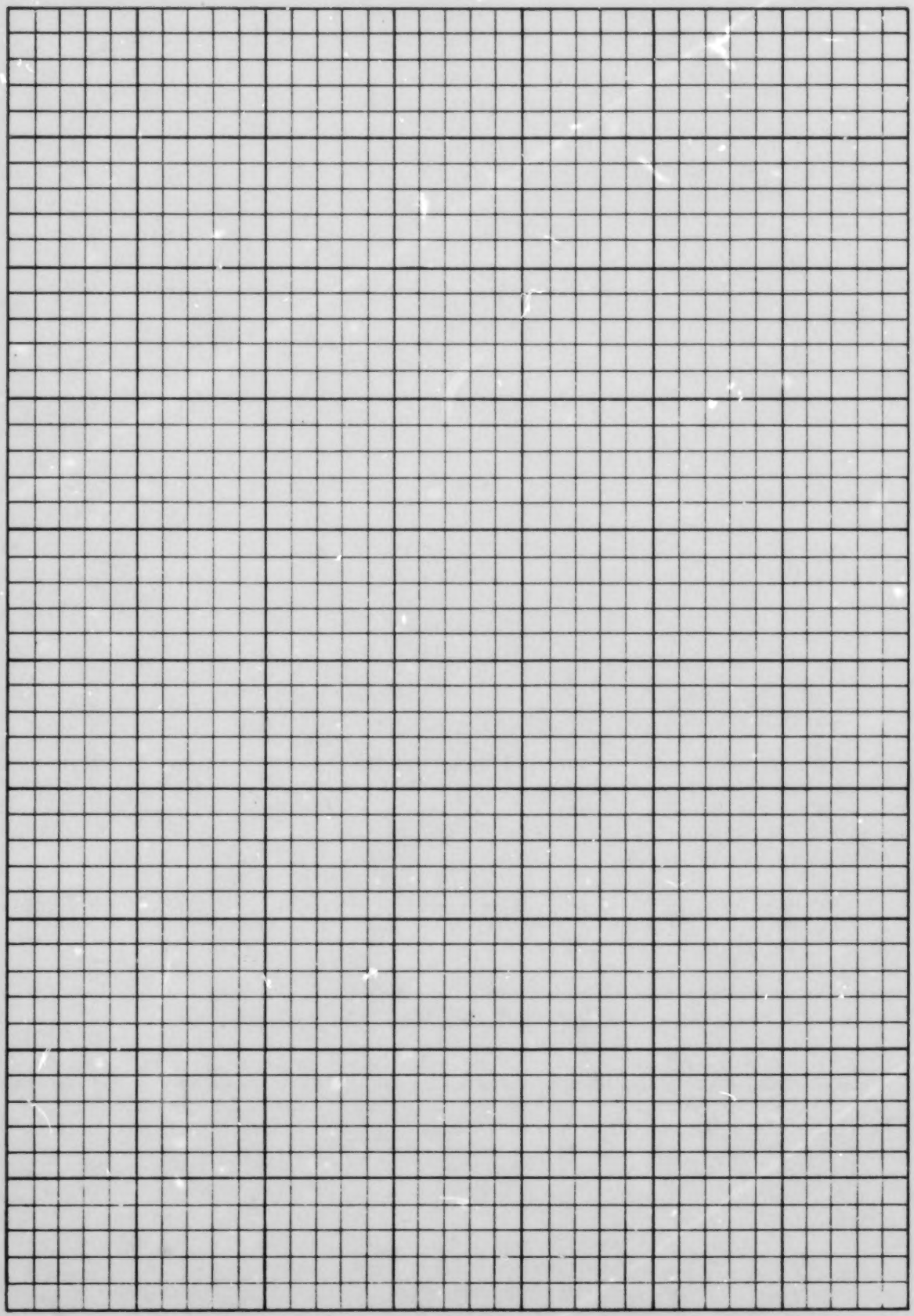
Year	Approx. Population of Deer
1907	6,000
1910	10,000
1915	25,000
1920	56,000
1923	100,000
1925	85,000
1930	30,000
1935	14,000
1938	9,000

If you had to comprehend and interpret the Kaibab deer population figures, which of the above two presentations would you prefer using? Certainly, it is obvious that the tabular presentation far surpasses the written paragraph presentation. However, is there still a better way - or, an equally effective means of communicating these data?

We are going to ask you to graph these same data using the graph paper found on the following page. A coordinate graph would probably be the most efficient. Please do this graph at this point in time.

You now have available three separate models of the Kaibab deer population data. Which would you prefer to use for interpreting data?

In keeping with the intent of this activity, we are going to ask you to use these data for the application of several science process skills. First, what conclusion can you produce from the deer population data? In science, the conclusion is a term that is often abused. A conclusion is a statement which summarizes a set of observations made regarding some particular phenomenon. It is not an inference, i.e., an explanation. With this definition in mind, produce a defensible conclusion from the data. The conclusion should adequately reflect all the data.



Conclusion:

What logical, scientific inference can be stated concerning these data? If you recall that an inference is an expression of an explanation of an observation, you will quickly realize that any inference stated on the data at this point would, by necessity, have to be quite vague and largely meaningless. Once again, this points up the need for knowledge in conducting the business of science.

With additional information, you should be able to infer at a high level of competence. Let's see how well you can infer with more information given.

Between 1907 and 1923, 300 coyotes and 600 mountain lions were killed on the Kaibab Plateau. For the years between 1907 and 1923, write the best possible inference you can from all the data available.

Inference:

More information might make your Kaibab inference even more powerful. Once again, we will provide additional information. As the deer herd began to increase, the range of the deer began to be overgrazed. During the years of decreasing deer populations, the range of the deer was so badly overgrazed that thousands upon thousands of deer died from starvation. What logical inference can you now pose based on all available data (1907-1938)?

My Best Inference:

The "All Purpose" Process Model*

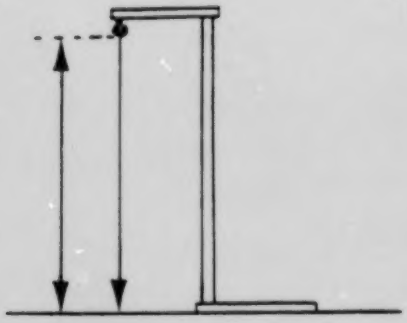
This process model incorporates several of the processes in which you have already received training plus a few new ones. These processes include observation, comparison, hypothesizing, controlling variables, data collection, graphing, data interpretation and experimentation.

Hopefully, upon completion of this model you will understand how many science processes or critical thinking skills can be used in combination during a problem-solving situation. Also, you should begin to see that processes are used in a certain sequence when scientific problem solving (i.e., experimentation) takes place. Finally, it is hoped that the relationship between process and product in science will be better understood.

In this model you will work with the pendulum. To make a pendulum system you will need some sort of support structure (one will probably be provided). From this support structure a string is suspended. At the bottom of the string you will need to affix some sort of weight holder like a shower curtain hook which will hold metal washers or a paper cup which can hold sand or marbles. The figures which follow in this model should help you perceive how a pendulum is set up.

Some of the variables or factors operating in this process model with which you need to become familiar are:

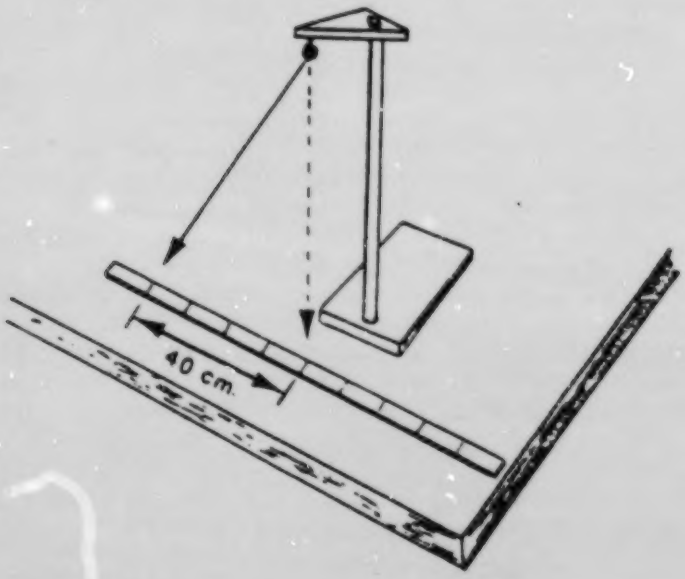
1. The length of the pendulum is the distance from the place the string is affixed to the structure to the bottom of the weight holder. See diagram below:



2. Weight in the pendulum system can be measured by: (1) the actual weight of the objects suspended in the system, i.e., the actual weight of the sand, the marbles, or the washers, or, (2) the total number of objects being suspended in the system, i.e., 2 marbles = 2 marble units; 5 washers = 5 washer units.

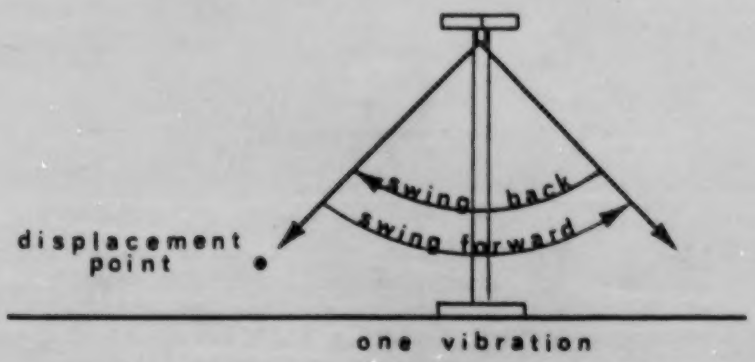
* Parts of this model were written by William J. Bluhm and adapted from Unit 1, Motion, in the fifth grade level of Elementary Science Learning by Investigation (ESLI), Rand McNally & Co., Chicago, 1974.

3. Displacement in the pendulum system is the distance the pendulum is moved from its stationary position. In the diagram below, the displacement is equal to 40 cm.



Displacement

4. Vibration in the pendulum system is a complete swing forward and back from the point at which the pendulum was displaced. Please refer to the following diagram.



5. Frequency is the number of vibrations that take place within a specified time span. For example, if the time span specified is 30 seconds, and the pendulum has 10 vibrations in 30 seconds, the frequency is 10 vibrations in 30 seconds.

The behavior of a pendulum might seem to be affected by several variables. In the activities that follow, you will have an opportunity to discover a set of relationships regarding certain variables and pendulum behavior. You might also be stimulated to seek answers because things did not turn out the way you expected them to, i.e., the outcomes were discrepant. Discrepant events many times excite the curiosity of scientists and are the phenomena which initiate scientific problem solving. Let's see if pendulums display any discrepancies. Let's investigate!

Experimental Activity 1 -

What do you think will happen to a pendulum's frequency if the weight in the pendulum system is increased?

In the space provided below, form a hypothesis that will describe what you think will happen. Remember to apply the rules for hypothesizing that you have learned.

Hypothesis: _____

_____

_____

_____

The validity of a hypothesis is determined by the results of experimental tests which scientists design and conduct. Your task is to design and conduct such an experiment to test the hypothesis written above. Systematic analysis of your hypothesis should help you design a good experiment.

As you examine the hypothesis you constructed, identify which variable will be manipulated. Weight? Right. Remember that in an experiment the manipulated variable (the variable over which the experimenter has control) is called the independent variable.

Identify the variable in the hypothesis which would respond to the weight manipulation. Frequency? Yes! As you will recall, in an experiment the variable that responds to the manipulated variable is called the responding or dependent variable.

In the experiment you design to test the relationship between increasing weight and pendulum frequency, what displacement and length will you use? Should you hold these variables constant, i.e., should you use the same displacement and the same length in each of the trials? Yes, for if you do not hold length and displacement constant (control the variables) you will need to redo the

experiment. Why? Because if you were to change the variables of weight, displacement, and length at the same time, you would be unable to determine which variable the frequency responded to--change in weight (?), change in displacement (?), or change in length (?). In an experiment, only one variable should be manipulated at a time. All other variables except the responding variable should be held constant or controlled.

Conduct the experiment you have designed to test the hypothesis you wrote. Record the data you collect in the table which can be found below.

Weight-Frequency Experiment Data

Trial	Weight	Displacement	Length	Frequency (30 Sec.)
1				
2				
3				
4				
5				
6				
7				
8				

Now, interpret your collected data in the space below:

Do the data support or refute your hypothesis? Mark your decision below:

Hypothesis decision: _____ Accept _____ Reject

_____ Suspend Judgment and Redo Experiment
Why? _____

_____

If you rejected your hypothesis, how would you restate it on the basis of the data you collected?

Hypothesis: _____

_____

_____

_____

Experimental Activity 2 -

Hypothesize as to what you think will happen to the frequency when displacement is increased in a pendulum system.

Write your hypothesis below.

Hypothesis: _____

_____

_____

_____

Design and conduct an experiment to test this hypothesis. Asnwer the following:

Which variable is the manipulated or independent variable? _____

_____

Which variable is the responding or dependent variable? _____

_____

Which variables are under control? _____

_____

Record the data you collect in the table found on the following page.

Displacement-Frequency Test Data

Trial	Weight	Displacement	Length	Frequency (30 Sec.)
1				
2				
3				
4				
5				
6				
7				
8				

Data Interpretation:

Hypothesis decision: _____ Accept _____ Reject

_____ Suspend Judgment and Redo Experiment

If you rejected your hypothesis, how would you restate it on the basis of the data you collected?

Hypothesis: _____

_____

_____

_____

Experimental Activity 3 -

Hypothesize as to what you think will happen to the frequency when length is increased in a pendulum system.

Write your hypothesis below.

Hypothesis: _____

_____

_____

_____

Design and conduct an experiment to test this hypothesis. Answer the following:

Which variable is the manipulated or independent variable? _____

_____

Which variable is the responding or dependent variable? _____

_____

Which variables are under control? _____

_____

Record the data you collect in the table found below.

Length-Frequency Test Data

Trial	Weight	Displacement	Length	Frequency (30 Sec.)
1				
2				
3				
4				
5				
6				
7				
8				

Data interpretation:

Hypothesis decision: _____ Accept _____ Reject

_____ Suspend Judgment and Redo Experiment

If you rejected your hypothesis, how would you restate it on the basis of the data you collected?

Hypothesis: _____

_____

_____

_____

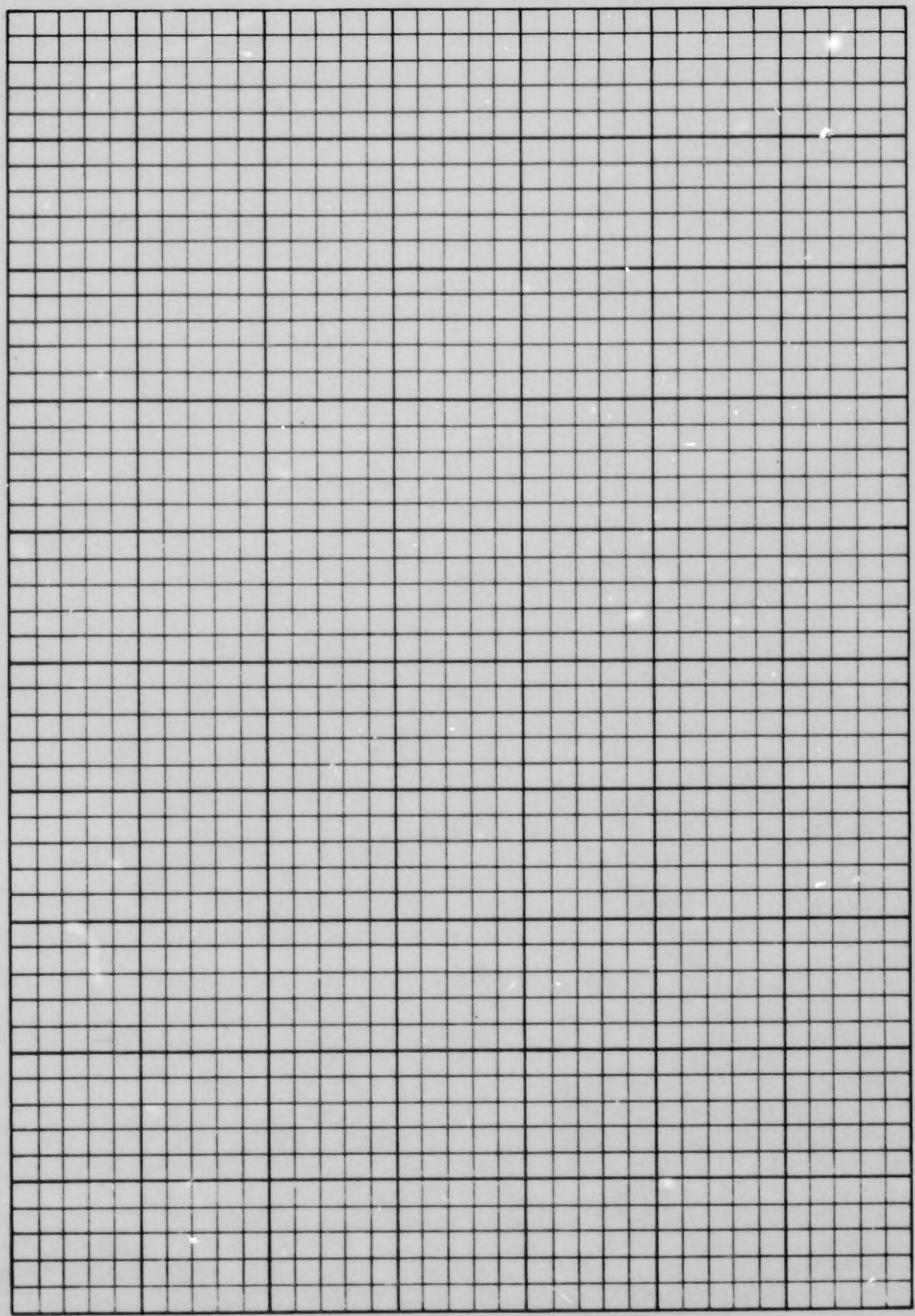
Next, on the following pages of graph paper, prepare three (3) graphs which illustrate the relationships between: (1) frequency and weight, (2) frequency and displacement, and (3) frequency and length. Use the data you collected in Activities 1, 2 and 3 in preparing the graphs. In each graph locate the independent variable on the horizontal axis and the dependent variable on the vertical axis.

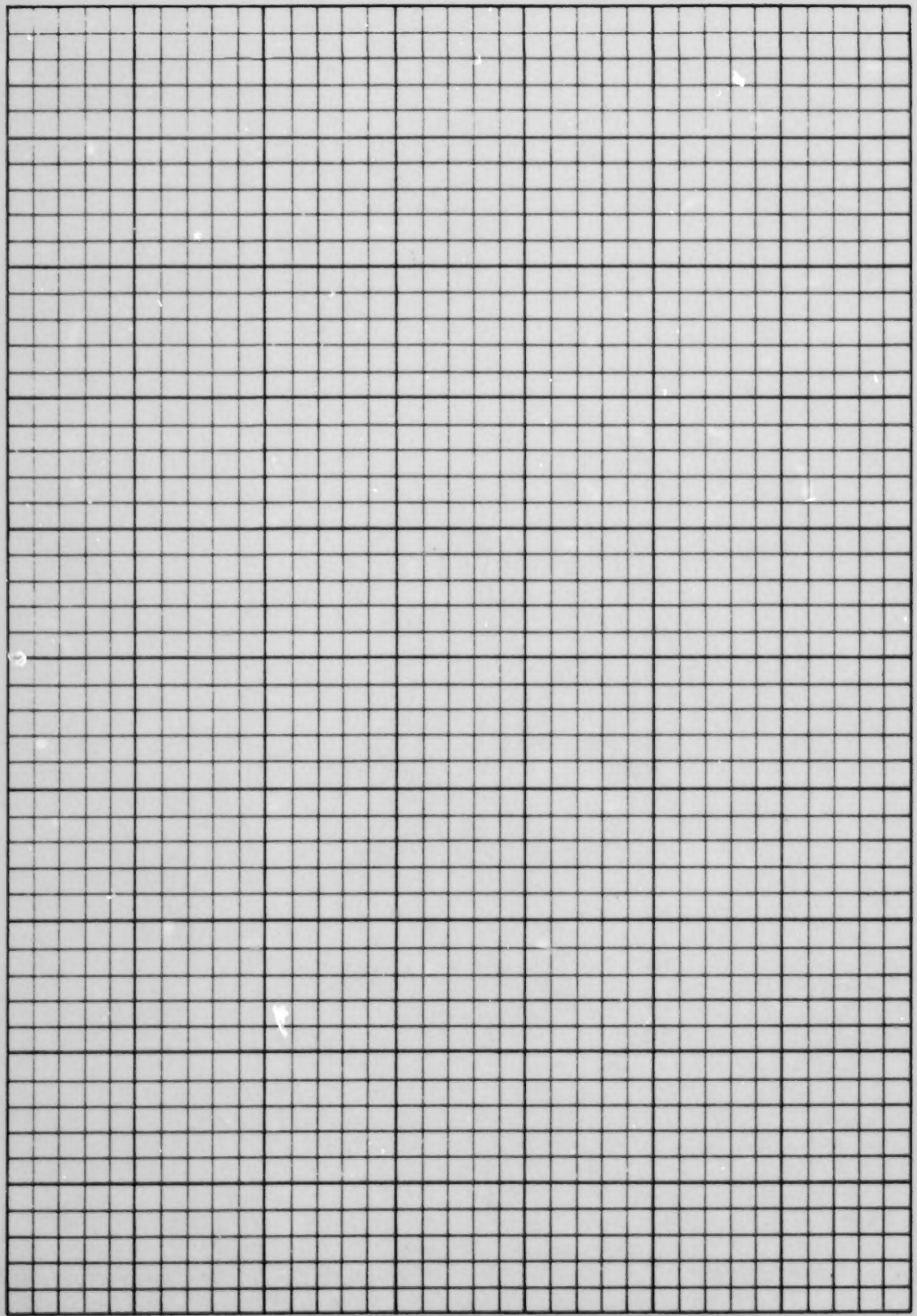
Although there can be many types of relationships between variables, they usually fall into one of three major types. These are (1) direct; (2) indirect; and (3) constant relationships. In a direct relationship the independent and dependent variables change in the same way, e.g., as one increases, the other increases or vice versa. In an indirect relationship if one variable changes, the other changes in the opposite direction, i.e., if the independent variable increases, the dependent variable decreases or vice versa. In a constant relationship situation, a change in the independent variable has no effect on the dependent variable. In the pendulum activity, what type of relationships did you find between (1) frequency and weight; (2) frequency and displacement; and (3) frequency and length?

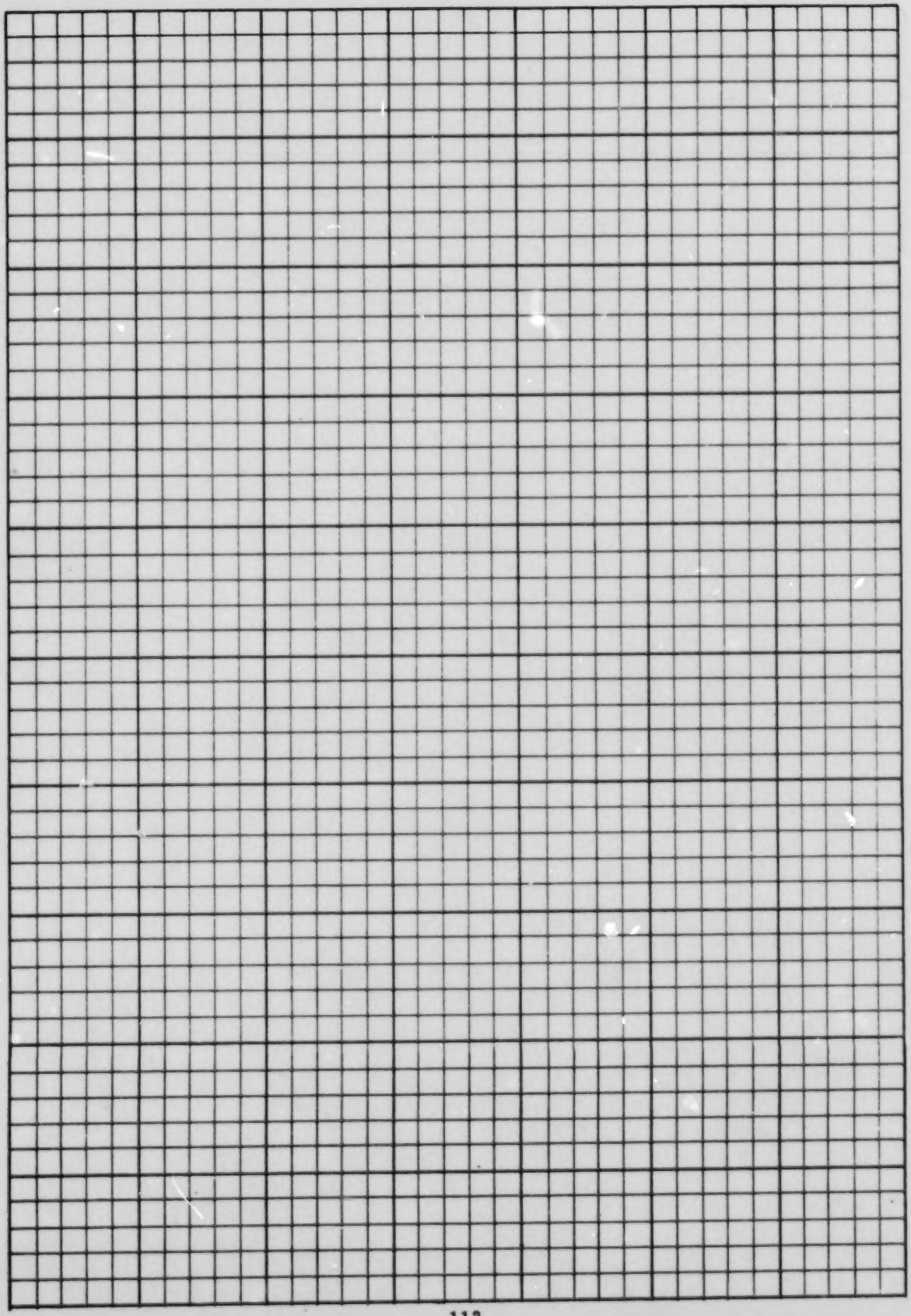
Upon the completion of the three graphs, respond to the following assignment: Interpret all graphed data. Use your data interpretation to produce a

rule or principle which summarizes the influence of weight, displacement, and length in a pendulum system.

Principle:







PART VI

The Affective Component: Scientific Attitudes and the Scientist

Performance Objectives

Subsequent to your interaction with Part VI you will be expected to be able to. . .

1. . . . identify those cultural stimuli which produce erroneous concepts of scientists.

2. . . . produce and logically defend a generalized description of a "scientist" based on all the information at your disposal relative to process, product and scientific attitudes.

3. . . . explain why the "scientific method" often taught in textbooks can be an erroneous concept concerning how a scientist goes about the business of doing science.

4. . . . on the basis of the anecdotes regarding Copernicus, Galileo, Charles Darwin and Jane Goodall, build a logical rationale as to why empiricism and theology are not philosophically compatible adversaries.

5. . . . defend the following statements: Scientists are empiricists but not free spirits. They have a responsibility to recommend how their scientific discoveries should be used by society.

6. . . . prepare a list of scientific attitudes as discussed in this section. Construct a rationale regarding the advantage(s) of each attitude in advancing and validating the work of science.

7. . . . defend the teaching of the characteristics of scientists and their scientific attitudes in elementary classrooms. Describe at least three methods of instruction which could be used by the classroom teacher to accomplish the development of said concepts.

8. . . . when presented with an anecdotal account of a scientific investigation, analyze the situation in terms of a) the scientific attitudes utilized by the scientist and b) the attitudes ignored or violated by him. Subsequently, on the basis of the above, evaluate the validity of the scientist's discovery.

9. . . . submit, in writing, using no more than 500 words, a biographical sketch of a scientist of your choice. Information in the report should include: cogent biographical data, personality characteristics, technological applications of his discovery(ies) and an identification of the scientific attitudes he used in his work.

The Affective Component: Scientific Attitudes and the Scientist

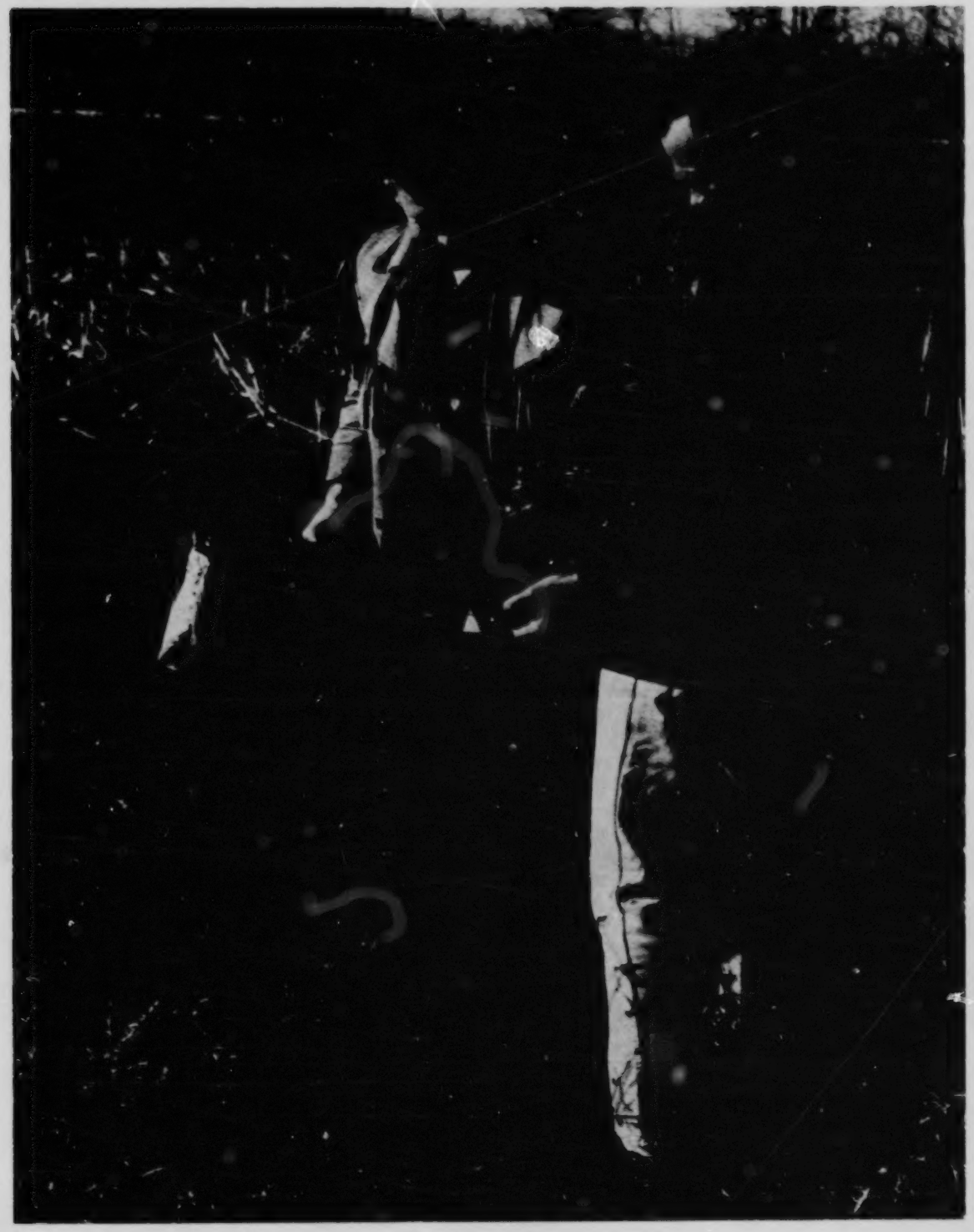
If asked to envision a scientist in your mind's eye, what kind of an individual would you "see"? Unfortunately, many would depict the scientist in a laboratory setting, bearded, with eyeglasses, preoccupied and white-coated, at times completely oblivious to the world around him. From where does one gather the stimuli with which to form such a generalization? If you are at all like most people, such a stereotype is arrived at via comic strips, the recent onslaught of horror movies, science fiction novels and various science-oriented, animated television programs. Yet, is this stereotype an accurate one, if in fact, an appropriate stereotype exists?

Unless it has been your fortune (or misfortune) to personally know a scientist or at least to study some of the biographical data concerning past and present scientists, you are probably a captive of the stereotypic "scientist concept". Realistic experiences such as those just mentioned might yield distinctly different perceptions of a scientist. You might then understand that scientists are human beings with likes and dislikes, joys, fears and worries just like other people. He (or she) may even have a family, financial problems, toothaches and all the other common concerns of any citizen. They are all individuals, with individual differences, so it would be most difficult to describe an average scientist.

There are hundreds of thousands of working scientists throughout the world. Amazingly, it is estimated that approximately 90% of all scientists who ever lived are still living today. These scientists work in many different kinds of investigations and in many science fields. An individual scientist may be a man or a woman from any nation, any race and any background with a personality and abilities which differ from the next scientist you might meet.

In terms of their work, all scientists do not operate "scientifically" in the same manner. Some scientists have great experimental ability. Some collect data using keen powers of observation, while a few use the data collected by the former groups and assemble the information mentally into meaningful theories. Each scientist may have his/her own way of attacking a scientific problem. Therefore, the manner in which science proceeds is really quite different from the series of steps often listed in textbooks and called the "scientific method".

Often, in order to appreciate the work of a scientist, it is important to know something about the period in which he or she lived or is living. Throughout history many scientists challenged widely accepted beliefs or drastically revolutionized man's thinking as a consequence of their new and unique findings. Some scientists, such as Copernicus and Galileo, were ridiculed and harrassed by their fellow citizens for they challenged prevailing knowledge which was supported by the clergy, who were the political leaders of the time. Interestingly, some of Galileo's discoveries verified the discovery of Copernicus concerning the movement of planetary bodies a half century after Copernicus had published his findings. Galileo supported the theory that the sun, not the earth, was the center of the universe! Demoting the earth from its position as center of the universe was most unsettling. Galileo's conservative opponents persuaded Pope Pius V to declare Copernicanism a heresy and Galileo was forced into silence in 1616. Later, Galileo was brought before the Inquisition on charges of heresy and was forced to renounce any views which supported Copernican Theory. Upon his death a few years later, his adversaries won another victory by refusing him burial in consecrated ground! It was not until verification by Isaac Newton, one hundred



and fifty years later, that both Copernican and Galilean astronomical theories were finally fully accepted.

There are many other instances of pioneering scientists who did not always received acclaim for their work. For example, Charles Darwin challenged theological dogma with his Theory of Evolution which was supported by empirical observations collected over many years. In fact, this controversy continues today. Louis Pasteur discovered bacterial causation for diseases and also, through his experimentation, yielded a death blow to the Theory of Spontaneous Generation. Pasteur was shunned by his own scientific colleagues for his efforts. His Germ Theory of Disease had violated one of the revered scientific precepts extant at that time! In 1960, an English anthropologist, Jane Goodall, chose to leave the civilized environment of London and presently lives in the wilds of Africa. To many people, this might seem like an absurd thing to do. Not many women would trade a life of relative comfort and culture for a tent and lorry in the African Bush! Yet in order for Jane to do her work, which involves the study of the behavior of chimpanzees, gorillas and vultures in their natural habitat, that's "where it's at!" Her observations on ape behavior have helped other scientists in their study of prehistoric man and the way he developed. Jane, like Darwin, has added much which may continue to stir the controversial pot of evolution.

Since scientists are invididuals with their own personal and work idiosyncrasies, one might begin to wonder just what is a scientist? Is there anything which links people such as Galileo, Copernicus, Darwin, Pasteur and Jane Goodall? Are there some commonalities among scientists? Most scientists would agree that there are.

In essence, scientists share a particular outlook or attitude which directs their work. A scientific affect (attitude) may very well be the common denominator among scientists. This attitudinal set has many components, not all of which are totally agreed on by scientists or science educators. However, the effect of scientific attitudes is so tremendous in terms of the scientific enterprise that a discussion of science without considering scientific attitudes would be as incomplete as studying science without mentioning intellectual processes.

In the earlier stages of the development of science, most investigation stemmed from man's urge and need to seek rational answers to his many questions. Curiosity was the stimulus for scientific study. Some current scientists still study the objects and phenomena of the universe because they are curious and receive intellectual satisfaction in discovering and interpreting them. This dynamic research for answers provides impetus for the vehicle of investigation. Without the attitudes of curiosity and intellectual satisfaction, science would never have reached the mammoth proportions it has.

However, as our culture has developed and become more complex, scientists are sometimes stimulated to investigate facets of the universe, not just because of the above attitudes but because economic, social and political demands are brought to bear on the choice of what scientists investigate. Often, the scientist cannot be a free spirit in his choice of work but must bend to needs as perceived by society. Although this may sound contradictory to the ethic of empiricism discussed in Parts I and II, this is not the case. When the scientist is involved in working on a scientific problem, he still operates empirically. He is a seeker of scientific truth regardless of the reason for his choice of investigation topics. At one time in history, the scientist could operate empirically and

not be concerned that practical applications be found for the results of his investigations. He did not need to be connected to or concerned with the uses of his findings. In our present age, scientists rarely have such freedom. In fact, as a scientist-citizen, he probably has a greater responsibility to use his influence to help determine what applications are made of his work. He has a set of responsibilities to make his opinions known to other citizens and to those who directly decide on technological applications even though he may have no direct control over what uses are made of his discoveries. Once he has communicated the results of his work, and made his knowledge public, it belongs to society, yet he can and should use his influence as a scholar to recommend how findings are applied.

Inherent within an empirical attitude is a firm conviction not to believe in superstitions. Scientists have a healthy respect for empirical logic. Nothing is intuitively based. Along with this is a belief that nothing, no matter how strange and mysterious, ever happens or could happen without a cause. Scientists proceed in their work with the belief that the universe is empirically lawful and orderly. This deterministic attitude directs the scientist to collect data in an effort to identify causal factors and in turn to manipulate these factors and thus modify and control the behavior he observes. Determinism is applied to all facets of scientific investigation, from the behavior of a caterpillar in search of food to the complexity of an atomic model.

Scientists are not necessarily humble individuals. At times some are justifiably proud and others even arrogant. When working scientifically, however, they must constantly repress tendencies to be dogmatic or to accept things blindly or unquestioningly. Instead, an attitude of healthy skepticism allows them to accept no statements as facts unless they are supported by sufficient proof. They demand verification and replication of the data. Coupled with skepticism are openmindedness and suspended judgment. A scientist attempts to search all avenues in terms of a given problem; to desist from forming an opinion on a given issue until he has investigated it. Humans who pre-form an opinion tend to accept only the facts that support that opinion. In science, this would be disastrous! Ideally, openmindedness and a desire to accept experimental verification are used by the scientist even when evidence which contradicts his/her hypothesis is produced. These two attitudes must be utilized to maintain science as a dynamic enterprise bent on ever-improving the exactness and completeness of the knowledge which science generates. Yet the scientist realizes that knowledge is tentative, subject to change. Also he realizes the conclusions he draws are not dogmatic, but based on probabilities. A scientist must have a positive approach to failure--for, indeed, failure does exist in science. Scientists operate on the premise that "this is not the right answer but at least it has been eliminated as a possibility. Try another alternative to the problem."

Surprisingly enough, some great scientific discoveries have been initiated as a consequence of this type of "failure". Oftentimes, unexpected results or chance happenings lead to a type of serendipity or chance discovery. The important portion of serendipity is being able to realize that an unexpected event may be the beginning of something important. For example, Alexander Fleming was not the first bacteriologist to observe that when molds contaminate bacterial cultures, the bacterial may not grow very well. But all other bacteriologists were simply annoyed by the fact that their cultures were contaminated and took the potential consequences of this phenomenon no further. Only Fleming thought it worthwhile to investigate the molds, even though it had nothing to do with the problem he was studying. As a result, in 1945 he shared a Nobel prize with

H. W. Florey and E. B. Chain for the discovery of penicillin and its therapeutic effect for the cure of various infectious diseases. This case study relates well to Louis Pasteur's quote, "Chance favors the prepared mind." Perhaps another scientific attitude component? Fortune does seem to favor the experimenter who is prepared to take notice of chance results. Unfortunately not all scientists are flexible enough to perceive the sometimes beneficial consequences of chance happenings.

A scientist is persistent! He thrives on the belief that there are solutions to the problems he attempts to solve. He is also cautious to separate hypotheses from solutions. When solutions are determined, however, he is equally cautious not to overextend the solution to situations other than those under experimentation. In his attempt to solve problems, he is motivated to be precise in his collection and communication of data. No vague, willynilly emotional statements of what experiences and/or observations might mean can be accepted. In a sense, precision and objectivity are linked to the empirical nature of a scientist's actions as he works. He has a high regard for facts and acts in accordance with them. A non-scientist often has the tendency to see only the facts he wishes to see and to react emotionally to contradictory evidence.

Scientists are also motivated to link the precision of their data collection with a firm attempt to quantify or mathematically communicate their data when at all possible. New mathematical techniques for reporting, analyzing and organizing data are constantly demanded by the scientist and judiciously used by him. Many scientists consider mathematics to be the handmaiden of science because of its ability to yield the probabilities regarding the validity of generated knowledge. The probability statements and laws of mathematics offer him confidence that his generated knowledge is not due to pure chance. It is the nonperceptive layman who myopically lives with the invalid comfort that life yields yes or no, all or none answers. Unfortunately but pragmatically, a scientist must live with a degree of uncertainty because often, there are no cut and dried, right answers.

As stated earlier, there probably is no total concensus concerning the scientific attitudes by which scientists are motivated. Nor can one generalize that all scientists apply all the discussed attitudes in their work or that the ones that they do apply are equally utilized. The type of scientific work being done as well as the personality involved determines much of a scientist's complete scientific affect.

What Does This Mean to the Teacher

To the pre or inservice teacher, the question may arise, "But what significance does a discussion of scientists and their scientific attitudes have for me and/or my students?" One answer lies in the examination of the Career Awareness Goal Cluster of Project Synthesis. Remember that awareness of scientists as real people and an understanding of the characteristics (skills and attitudes) of a scientist are subgoals of this scientific literacy component. Said in another way a discussion of scientists is valuable in order to help children formulate an accurate concept of what scientists are like. Mass media has done far too "good" a job of creating the stereotype originally described in this section. Rather than continuing the creation of such a stereotype, one of the purposes of valid science education should be to instill a proper perspective concerning scientists and their work. A teacher can approach such education in many ways. In all grades, if the

opportunity exists, working scientists can be invited into the classroom to speak to the students about their work and themselves. (By all means do speak with the scientist yourself beforehand to assure that you have made a wise choice of speakers). In this way, children are presented with fact rather than fiction. Similarly, they have a real role model with which to associate. If your school is located near a university or firm where scientific work is taking place, a field trip to see scientists in action can usually be arranged. Many organizations are quite willing to facilitate this.

Another approach is the use of actual biographies of scientists. Students can research not only the personalities but the discoveries of such famous scientists as Archimedes, Linnaeus, William Harvey, Pierre and Marie Curie, Linus Pauling and many others. Excellent trade books, filmstrips and films are available besides the traditional pedantic encyclopedia. Oral and written reports can be prepared. Such historical research can also indicate to the students (if the students are themselves aware of them) the specific attitudes and intellectual processes the scientists used. Often the children will discover the ways that some scientists have changed the course of human history even though this was not the scientist's intent.

Another teaching suggestion is to use some recently developed, low cost materials which expose students to scientists and scientific careers. Two such teaching aids are:

1. Search for Solutions, a nine-part film series introduces students to working modern scientists. The films let the audience see nine different ways scientists pursue answers to problems. Both male and female scientists are shown as well as people from different racial backgrounds. Interestingly, one of the scientists is blind!

Each film is 18 minutes long. The content is most appropriate for intermediate, and junior and senior high school students. The teacher ordering these materials will also receive a teaching guide which contains a wealth of background materials and teaching suggestions. The films can be ordered (free-of-charge) from:

The Search for Solutions
708 Third Avenue
New York, New York 10017

2. COMETS (Career Oriented Modules to Explore Topics in Science) are career-oriented materials for use by students in grades 5-9. COMETS Science is a 450 page notebook which presents over 100 activities for use in physical, earth and life sciences. COMETS Profiles, a second volume includes 24 biographical sketches of women in science careers as well as optional language arts activities to develop comprehension, vocabulary and writing skills. Trial editions of COMETS Science and Profiles are available at cost ($19.95 each or $1.50 each for sample lesson) from

COMETS
205 Bailey Hall
University of Kansas
Lawrence, Kansas 66045

In terms of scientific attitudes, most are highly applicable for non-scientists and for students for general education purposes. An awareness and use of such attitudes as openmindedness and verification of information should help students not only in science class but in their daily lives.

In Summary - A scientist is a human being who utilizes various scientific processes to make careful inquiries into the objects and happenings around him/her. He is able to put his findings into an organized and meaningful system of knowledge that can be used by other human beings. A scientist is intelligent and able to solve problems. The two aspects which set him/her aside from others are their unique abilities to use the skills of science and the attitudes with which they go about the business of being scientific. Some of the attitudes are: curiosity, empiricism, intellectual, satisfaction, aversion to superstitution, determinism, skepticism, openmindedness, suspension of judgment, willingness to change opinion, acceptance of experimental verification, persistence, a positive approach to failure, precision, a view to capitalize on chance results, belief in the potential solutions to scientific problems, objectivity, a high regard for facts and acceptance of mathematical probabilities to validate knowledge. Students should be made aware of the realities of what scientists and their attitudes are in order to help them have a valid concept of the entire scientific enterprise.

A Problem Situation

Now that you are aware of some of the scientific attitudes, try your hand at analyzing the following anecdotal situation. Read the following passage carefully and answer these questions.

1) What scientific attitudes were used by Mr. Jones?
2) Which attitudes were ignored or violated?
3) How much validity can be given to Mr. Jones' scientific discovery? Why?

THE FOGS OF AUGUST - THE SAGA OF CLY MAT JONES

Seldom is science blessed with a man of the brilliant and articulate nature of Mr. Cly Mat Jones, an unsung but dedicated meteorological researcher. Although odd to claim so much for a non PhD, one must rememer that Cly Mat Jones was mostly self-educated, his only genuine experience with graduate education being a brief year's work at the Southern Mississippi Institute of Climatological Studies (SMICS) on a grant from the Western Utah Mormon Foundation. Cly-s ethical nature made him surrender the remainder of his grant when he realized that no amount of research could prove the influence of polygamy on God's decision that western Utah should remain arid.

Soon after leaving SMICS, Cly moved to southern Illinois where he hoped to gain admission to the Graduate Program in Southern Illinois University's renowned Department of Geography. This strategy was doomed to failure, however, when the Graduate School refused to accept credits earned

at SMICS. Frustration threatened to consume Cly in his search for the PhD. Disheartened and out of funds, Cly took a job in a small grocery and general store in Vienna Heights, Illinois. Vienna Heights proved kind to our hero as the local citizenry soon grew to respect Cly's bright mind and appealing but diarrheic verbal behavior.

August of 1970 proved to be somewhat discrepant which stimulated Cly's renewed interest in meteorology. Trade at the general store was not always time consuming and many an hour was spent chatting with the local retired and unemployed populace. This particular August started out to be foggy in the evening hours and this phenomenon prompted several "old timers" to comment that it would surely be a snowy winter if the fogs kept up throughout the month. Cly smiled to himself when he was told that the number of August fogs would accurately predict the number of snows the following winter.

Cly had little better to do, so he began recording the dates on which fogs were observed in and around Vienna Heights. Further, his curious mind stimulated him to record whether the fogs were light valley fogs or heavy ones which extended over hill and dale.

Winter followed fall and Cly decided to keep a meteorological chart of the snowfall in and around Vienna Heights. As midwinter approached, Cly was astounded to find that, indeed, there was a correlation between his foggy and snowy data. In addition it appeared as though there was, in fact, a relationship between the amount of snowfall and the intensity of the fog as one went back into weather records and checked corresponding fogs and snowfalls. By spring, there was no doubt in Cly's mind - there was a relationship between the fogs of August and snowfall the following winter. The incidence of fogs and snowfall had a .97 correlation and the intensity correlation was .76. Both correlations were statistically significant. Cly had definitely shown a cause and effect relationship between the fogs of August and subsequent snowfalls!

Cly knew a good scientific finding when he saw one. He carefully prepared a paper on his findings and submitted it to the Royal Canadian Society on Climatological Phenomena. It never appeared in the Society's journal, however, because the editor was afraid that the Society's members would scoff at Cly - and the Society. Undaunted, Cly took his manuscript and went on a hitchhiking tour of the Midwestern U. S. geography departments only to be rebuffed at every door. Cly remembered Darwin, Galileo, and Pasteur and remained faithful to his own genius. Even the Vienna Heights Senior Chamber of Commerce voted to submit Cly's name as a candidate for a Nobel Prize, but they couldn't find the address.

So - Cly's genius remains unsung, probably because he was a man ahead of his times. Cly rests quitely now in the Vienna Heights Cemetery - the victim of a mysterious accident in 1972 - in a fog - in August.

PART VII

Models for Action -- Modern Science Programs

Performance Objectives

Subsequent to your interaction with Part VII you will be expected to be able to. . .

1. . . . identify and discuss the distinctive features of SAPA, SAPA II, ESS, and SCIS as specified by your reading assignments and your instructor. Similarly, you will be able to identify and discuss these programs' physical and educational characteristics (as well as any limitations) as specified by your instructor.

2. . . . define the meaning of the term "process" as specified by your SAPA reading assignment.

3. . . . explain and defend the following statement from an educational perspective:

> "One of the goals of SAPA is to provide the child with knowledge that is generalizable to new situations."

4. . . . identify the terminal goals for students who have participated in SAPA as specified in Part VII.

5. . . . identify the degree to which the SAPA program demonstrates internal educational consistency among its major components, i.e., 1) objectives, 2) curricular design, 3) instructional activities and 4) evaluation procedures. Further, describe the characteristics of each of the four SAPA components.

6. . . . state specifically how the competency measure (evaluation) in Predicting 4 - The Suffocating Candle relates to the training the students receive in the laboratory. In other words, in what ways is the competency measure consistent and/or inconsistent with the educational experiences of the children?

7. . . . define and differentiate between the terms extrapolation and interpolation and relate these to the process of prediction. Also, be able to define or explain the term experimental error.

8. . . . demonstrate (in class) a competency with the behaviors expected of students while experiencing Predicting 4 - The Suffocating Candle.

9. . . . describe how ESS provides for flexibility in terms of its unit approach, its grade level application of units, and its open-ended nature.

10. . . . explain why the ESS teacher must be highly competent with both instructional and evaluation methods. Similarly, explain why the ESS teacher must be one who is able to cope with a relatively unstructured learning environment.

11. . . . describe how much of the ESS program is consistent with the generalized philosophy of the "open classroom".

12. . . . state correctly the overall objective of SCIS as specified in your readings. Include in your response the scientific literacy component as well as relating the component to knowledge, skills, and attitudes.

13. . . . describe how the content of SCIS reflects a conceptual hierarchy and successfully compare this hierarchy with that of SAPA.

14. . . . cite evidence to support the contention that the entire SCIS program relates to an overall concept of "interaction".

15. . . . defend the position that the knowledge component of SCIS has great merit from a general education perspective.

16. . . . accurately compare SAPA, SAPA II, ESS, and SCIS (and other strategies described in this methods course, including the classic textbook approach) in all of the following dimensions:

a. specific intent of the programs.
b. scope of the programs including content areas and grade levels.
c. degree of structure in the programs.
d. how lessons are sequenced.
e. numbers of units (lessons) taught in the programs.
f. how objectives are communicated to teachers and students.
g. evaluation techniques used.
h. how much reading is required of students.
i. experiential nature of the programs.
j. materials provided by publisher for the teacher.
k. whether inservice (or preservice) teacher training is necessary.

17. . . . defend the position that, although the SAPA, SAPA II, ESS, and SCIS programs differ considerably, all reflect an inductive approach to learning.

Models for Action -- Modern Science Programs

Introduction

Although tens of thousands of elementary school children still experience either no science at all in their classrooms or "read about science" programs, numerous experientially-based, sophisticated science programs exist. These modern science programs have been developed over the past two decades by a variety of agencies operating with substantial grants of money from both private and federal sources.

Although these science programs reflect somewhat differing educational philosophies, they have some significant common attributes. All are inquiry oriented, i.e., children DO science and INDUCTIVELY generate knowledge. All permit a wide range of students to experience success in science. All deemphasize the traditional relationship between reading ability and achievement, i.e., students experience almost no reading at all or a minimal amount. All have been

trial tested by using them with children. Further, trial testing in schools across the nation resulted in revisions of materials before being commercially produced.

All of the modern programs demand special training for teachers in order to be maximally effective. Although many educators seem to constantly search for panaceas or their own private instructional Valhallas, these are not likely to be found in modern science programs. Any program is only as good as the teacher using it! The modern programs demand, besides training, dedication and hard work on the part of the classroom teacher. They also demand the support of the administration and the community. The school board must be willing to financially support the acquisition and implementation of the program as well as allocate teacher preparation and planning time.

Even though significant problems can arise in the implementation of modern science programs, they are highly recommended. For the first time, teachers have available science materials which substantially narrow the gap between what is offered the students and their ability to function intellectually. These programs have the ability to help transform educational lip service concerning scientific literacy into action and the subsequent reality of intellectually competent human beings. Although the programs do not reflect all of the Project Synthesis goals, they do address some of them.

In this section we will deal with three of the most popular but divergent modern programs. Sufficient background information and experiences will be provided to permit the acquisition of functional concepts concerning each. These experiences do not guarantee that you will become expert in any one of these programs. However, you will acquire realistic and functional perspectives concerning these programs from both teacher and student standpoints.

Finally, the authors realize that you may not teach in a school which has adopted one of these programs. Unfortunately, results from a recent survey of elementary science programs across the U. S. indicate that fewer than 10% of U. S. elementary schools use these programs. Then, "Why study them?" you may ask. The reason rests in the title of this section - Models for Action. Examination of these curricula will offer you valuable ideas for organizing and delivering sound science instruction. Each program can offer you a model for science teaching. Each model has been successfully tried and tested. Further, you should come away with ideas for activities presented in educationally sound ways. Finally, knowledge of these programs may allow you to integrate the programs in your own classroom or, perhaps, into your schools if you are called upon to serve on a science curriculum adoption committee.

Science: A Process Approach (AAAS)

Science: A Process Approach (SAPA), or the AAAS Program, as it is sometimes called, is a K-6 science program developed by the Commission on Science Education of the American Association for the Advancement of Science. The program was designed by both scientists and educators working cooperatively over a six year period. It was originally commercially handled by the Ginn-Xerox Corporation. Currently, the materials may be obtained from Delta Education, Inc., P. O. Box M, Nashua, N. H. 03061-6012.

A thorough description of the program is contained in AAAS Miscellaneous Publication 67-12 entitled Science - A Process Approach - Purposes - Accomplishments - Expectations. The following represents the substantive structure of that publication and is reprinted here with with permission of the AAAS Commission on Science Education, 1973.

Science - A Process Approach - Purposes - Accomplishments - Expectations

The development of an elementary science curriculum called *Science — A Process Approach* is now approaching completion. This curriculum, for children in kindergarten and grades one through six, has been developed by the commission on Science Education of the American Association for the Advancement of Science. The six-year effort has been financially supported by the National Science Foundation, and has involved the enthusiastic participation of more than a hundred scientists and educators, representing a wide spectrum of backgrounds, interests, and specialized knowledge.

Initial plans for the design of this new curriculum were formulated in two conferences held in the summer of 1962. On the basis of these conferences, the Commission on Science Education outlined a projected elementary science program which would emphasize the laboratory method of instruction and would focus upon ways of developing basic skills in the processes of science. The processes include observing, classifying, measuring, predicting, and other skills needed for scientific investigations. The annual cycle of activities which has been repeated each year has followed this sequence: (1) planning for development, during winter and spring; (2) a "summer writing conference" of scientists and teachers; (3) a fall period of revision, editing, and publication of experimental materials; (4) a simultaneous activity, beginning in the fall and extending to the next summer, of trying out the newly developed materials in a group of participating schools in various parts of the country.

Since 1964, a *Newsletter* describing important events and outcomes of this developmental cycle has been published (see References: AAAS Commission on Science Education, 1964-68). A summary of the program's history is given in the *Newsletter*, Volume 3, No. 2 (1967). Additional accounts of early events are given by Mayor (1962) and by Livermore (1964).

Characteristics of the Program

Science — A Process Approach shares certain purposes and characteristics with other modern science curricula. Like them, it is designed to present instruction which is intellectually stimulating and scientifically authentic. Like other programs, it is based upon the belief that an understanding of the scientific approach to gaining knowledge of man's world has a fundamental importance as a part of the general education of any child.

The program also has characteristics which make it different from other curricula in elementary science. The noteworthy and distinctive features of *Science — A Process Approach* may be summarized as follows:

1. Instructional materials are contained in booklets written for, and used by, the teacher. Accompanying kits of materials are designed for use by teacher and children. Except for certain data sheets in the later grades, there are no printed materials addressed to the pupil. What the teacher does is to organize and set up science problem situations designed for participation by the children.
2. The topics covered in the exercises sample widely from the various fields of science. The exercises are ordered in sequences of instruction to provide a developmental progression of increasing competence in the processes of science.
3. Each exercise is designed to achieve some clearly stated objectives. These are phrased in terms of the kinds of pupil behavior which can be observed as outcomes of learning upon completion of the exercise.
4. The coverage of fields of science is broad. Mathematics topics are included, to be used when needed as preparation for other science activities. Some of the exercises draw from the social and behavioral sciences. Most involve principles in physics, biology, and chemistry, with a lesser representation of earth sciences and astronomy.

5. What is to be learned by the children is an accumulative and continually increasing degree of understanding of, and capability in, the processes of science. Progress begins in the kindergarten with observation and description of object properties and motion, and advances through the sixth grade to the design and conduct of scientific experiments on a variety of topics.
6. Methods for evaluating pupils' achievement and progress are an integral part of the instructional program. The exercises contain tests of pupil achievement reflecting the objectives of the exercises and providing means of assessing outcomes. In addition, separate measures have been developed for use in determining pupil attainments in process skills prior to instruction.
7. *A Commentary for Teachers* and a *Guide for Inservice Instruction* include essential general information on the science principles and processes involved in the program, and a set of exercises providing opportunities for teachers to practice relevant instructional techniques.

The Meaning of Process

There are a number of ways of conceiving of the meaning of "process" as exemplified in *Science — A Process Approach*. First, perhaps, it should be mentioned that an emphasis on process implies a corresponding de-emphasis on specific science "content." Of course, the content is there — the children examine and make explorations of solid objects, liquids, gases, plants, animals, rocks, and even moon photographs. But, with some few notable exceptions, they are not asked to learn and remember particular facts or principles about these objects and phenomena. Rather, they are expected to learn such things as how to observe solid objects and their motions, how to classify liquids, how to infer internal mechanisms in plants, how to make and verify hypotheses about animal behavior, and how to perform experiments on the actions of gases. For example, in an exercise on the movement of liquids in materials (Part E), the children learn to design and carry out experiments on the relation between kinds of materials and rate of movement of liquids within them, including the control and manipulation of relevant variables; but they are not required to learn particular facts about the rate of liquid movement in blotting paper, fabrics, sand, clay, or other materials employed in the exercise. Such facts may be incidentally learned, and may be useful to the child, but the primary objective is one of learning to carry out the process of controlling variables in an experiment.

A second meaning of process, referred to by Gagné (1966), centers upon the idea that what is taught to children should resemble what scientists do — the "processes" that they carry out in their own scientific activities. Scientists do observe, and classify, and measure, and infer, and make hypotheses, and perform experiments. How have they come to be able to do these things? Presumably, they have learned to do them, over a period of many years, by practicing doing them. If scientists have learned to gain information in these ways, surely the elementary forms of what they do can begin to be learned in the early grades. This line of reasoning does not imply the purpose of making everyone a scientist. Instead, it puts forward the idea that understanding science depends upon being able to look upon and deal with the world in the ways that the scientist does.

The third and perhaps most widely important meaning of process introduces the consideration of human intellectual development. From this point of view, processes are in a broad sense "ways of processing information." Such processing grows more complex as the individual develops from early childhood onward. The individual capabilities that are developed may reasonably be called "intellectual skills," a phrase which many would prefer to the term "processes."

When one considers processes as intellectual skills, certain general characteristics become apparent. One of the most important is the degree of generalizability one can expect in human capabilities of this sort. The typical development of intellectual skills, as Piaget's work (cf. Flavell, 1963) amply reminds us, is from the very concrete and specific to the increasingly abstract and general. Highly general intellectual skills are typically formed over a period of years, and are thought to depend upon the accumulated effects of learning a considerable variety of relatively concrete principles. Accordingly, the skills which *Science — A Process Approach* is designed to establish begin in highly specific and concrete forms, and increasing generality of these skills is systematically provided for by a planned progression of exercises. Evidence shows that these skills do generalize to a variety of new situations

(*Newsletter*, 1967, Volume 3, No. 3; *An Evaluation Model and Its Application*, 2nd Report, 1968). The instructional program of *Science — A Process Approach* attempts to deal realistically with the development of intellectual skills, in the sense that the goals to be achieved by any single exercise are modest. In a longer-term sense, substantial and general intellectual development is expected to result from the cumulative effects of an orderly progression of learning activities.

Processes and Intellectual Development

There is, then, a progressive intellectual development within each process category. As this development proceeds, it comes to be increasingly interrelated with corresponding development of other processes; inferring, for example, partakes of prior development of skills in observing, classifying, and measuring. The interrelated nature of the development is explicitly recognized in the kinds of activities undertaken in grades four through six, sometimes referred to as "integrated processes," including controlling variables, defining operationally, formulating hypotheses, interpreting data, and as an ultimate form of such integration, experimenting.

A brief description of the expected sequence of development in both basic and integrated process categories is as follows. More complete descriptions of these processes are contained in the *Commentary for Teachers* (1968).

Observing. Beginning with identifying objects and object-properties, this sequence proceeds to the identification of changes in various physical systems, the making of controlled observations, and the ordering of a series of observations.

Classifying. Development begins with simple classifications of various physical and biological systems and progresses through multi-stage classifications, their coding and tabulation.

Using Numbers. This sequence begins with identifying sets and their members, and progresses through ordering, counting, adding, multiplying, dividing, finding averages, using decimals, and powers of ten. Exercises in number-using are introduced before they are needed to support exercises in the other processes.

Measuring. Beginning with the identification and ordering of lengths, development in this process proceeds with the demonstration of rules for measurement of length, area, volume, weight, temperature, force, speed, and a number of derived measures applicable to specific physical and biological systems.

Using space-time relationships. This sequence begins with the identification of shapes, movement, and direction. It continues with the learning of rules applicable to straight and curved paths, directions at an angle, changes in position, and determinations of linear and angular speeds.

Communicating. Development in this category begins with bar graph descriptions of simple phenomena, and proceeds through describing a variety of physical objects and systems, and the changes in them, to the construction of graphs and diagrams for observed results of experiments.

Predicting. For this process, the developmental sequence progresses from interpolation and extrapolation in graphically presented data to the formulation of methods for testing predictions.

Inferring. Initially, the idea is developed that inferences differ from observations. As development proceeds, inferences are constructed for observations of physical and biological phenomena, and situations are constructed to test inferences drawn from hypotheses.

Defining operationally. Beginning with the distinction between definitions which are operational and those which are not, this developmental sequence proceeds to the point where the child constructs operational definitions in problems that are new to him.

Formulating hypotheses. At the start of this sequence, the child distinguishes hypotheses from inferences, observations, and predictions. Development is continued to the stage of constructing hypotheses and demonstrating tests of hypotheses.

Interpreting data. This sequence begins with descriptions of graphic data and inferences based upon them, and progresses to constructing equations to represent data, relating data to statements of hypotheses, and making generalizations supported by experimental findings.

Controlling variables. The developmental sequence for this "integrated" process begins with identification of manipulated and responding (independent and dependent) variables in a description or demonstration of an experiment. Development proceeds to the level at which the student, being given a problem, inference, or hypothesis, actually conducts an experiment, identifying the variables, and describing how variables are controlled.

Experimenting. This is the capstone of the "integrated" processes. It is developed through a continuation of the sequence for controlling variables, and includes the interpretation of accounts of scientific experiments, as well as the activities of stating problems, constructing hypotheses, and carrying out experimental procedures.

Description of Intellectual Development

Descriptions of these sequences of intellectual development serve a number of purposes in the execution of the educational program embodied in *Science — A Process Approach*. These descriptions are contained in behavioral hierarchies, which bear a derivative relation to the learning hierarchies described by Gagné (1965) for smaller portions of various curricula. A chart depicting the behavioral hierarchies for all of the simpler processes has recently been published (Process Hierarchy Chart, 1967), and an explanation of them is also given in booklets introducing each Part, entitled *Description of the Program*.

The behavioral hierarchies constitute the "skeleton" of *Science — A Process Approach* and the rationale for selecting and ordering the sequence of exercises. Thus the behavioral hierarchies orient the teacher to the purposes of the program, or of any portion of it. The teacher may examine the progression of behavioral development depicted in these hierarchies, and derive from them a view of where teaching starts and where it is expected to go. In addition, they show the interrelationships between any one exercise and others which precede or follow it, including those primarily devoted to other processes. To aid the teacher in maintaining this viewpoint towards the progressive development of processes, there is included in each exercise a section showing the relevant preceding steps and subsequent steps in the behavioral hierarchy. This section is, in actuality, simply a small portion of the entire hierarchy, providing the teacher with a rather specific view of what has gone before and what is coming next. The interpretation of such diagrams is expected to be: (1) here are the prerequisites for the present exercise; (2) here is what the child is expected to learn in this exercise; and (3) this is what the exercise will prepare him to undertake in later learning.

The second major use of the behavioral hierarchies is as guides to the assessment of student achievement and program evaluation (*Newsletter*, 1967, Volume 3, No. 3; Walbesser, 1965). Initial evaluation of the student, to determine whether or not he has achieved the objectives of each exercise, is carried out by performance tests based upon the objectives stated in the exercises themselves. Such tests, however, are designed to be consistent with the behavioral hierarchies, so that in each case what is being measured is a new achievement, and not something that has already been achieved as a result of some earlier exercise.

In addition, provision must be made to measure achievement in a sense other than as the immediate effects of instruction; in fact, in a developmental sense. The basis for such measurement is again the developmental sequence of the behavioral hierarchy, represented in a test which attempts to assess how far a pupil has progressed in each process (*Science — A Process Approach, The Process Instrument*, 1970.) Finally, the hierarchies also guide the development of measures of achievement which are "terminal" to the program, insofar as they help to define what the minimum set of behaviors may be for children who have participated in the program for a period of years.

Purposes of the Program

The major characteristics of *Science — A Process Approach* which have been described surely serve in large part to convey what the program is all about. Some additional understanding of the approach, however, may be gained from an account of the purposes which have guided the effort. An important statement of these purposes was prepared at an early stage of development by a committee of the Commission on Science Education (*Science — A Process Approach, Commentary for Teachers*, 1970). In addition, several papers dealing with the goals of various aspects of the development were prepared at different points along the way and are collected together under the title *The Psychological Bases of Science — A Process Approach* (1965).

General education. From the outset, it has been a guiding purpose to develop a curriculum which could become part of the general education of every child. The goal has not been to produce students of science who have a large amount of highly specialized knowledge. Rather, the aim is for every child to acquire the basic knowledge and point of view which provide him with a highly generalized method of gaining an understanding of himself and the world in which he lives.

Preparation for systematic study of scientific disciplines. Another important guiding purpose has been to provide the student in the elementary grades with some highly generalizable intellectual skills, and some knowledge of scientific procedures for gaining new knowledge, which can serve as a springboard for later study of any of the sciences. There are some very basic ideas, it is believed, which are important to the understanding of systematic science, and which cannot be readily identified as portions of the traditional elementary curriculum. It is these ideas that are intended to be represented as the "processes" of the new science curriculum.

Generalizability of knowledge. A related aim is that of providing the child with the kind of knowledge that is generalizable to new situations. In part, this is accomplished by the use of a variety of content. In part, it is attempted by asking the child to practice making generalizations from one field of science to another. Controlling variables in an experiment on rusting of iron may be followed by an exercise that poses a problem of controlling variables in plant growth.

Level of achievement. Certainly, the program aims for a level of achievement in understanding science and making scientific investigations which has not heretofore been attained by elementary school students. The purpose is to give these children capabilities for thinking and acting in the realm of science which go far beyond what has previously been customary. It is hoped that such capabilities may be applied in all their pursuits, not solely to the further study of scientific subjects.

Intellectual challenge. The materials of the program were prepared with the aim of presenting children with intellectual challenges. Pupils are required to remember few "facts," and those few will most probably be retained without effort. However, they are frequently asked to think, to use reasoning, and to invent methods and explanations. This is considered to be an important part of what is meant by learning to use science "processes."

Pupil interest. The well-known principle of proceeding in instruction from the familiar to the unfamiliar is used throughout the program. The attempt is made to appeal to initial pupil interest, and to maintain it as new problems are introduced. Thus one important goal of instruction is to bring about a broadening of pupil interest in the many fields of science. It is hoped that the child will come to recognize many new problems, previously unknown to him, which can be viewed scientifically; and that over the course of the program he will develop a lasting interest in science, whether or not he chooses it for a life work.

Achievement motivation. Besides the motivation of curiosity and intellectual challenge, the program intends to make use of achievement motivation. Comments from teachers and the measured achievements of children during the tryout period have been used as bases for revisions and adjustments in the exercises designed to accomplish this purpose. The exercises are aimed at *all* children, not solely the bright ones. The objectives are intended to be not too difficult for the vast majority of children to achieve. When they are achieved, this accomplishment will, it is hoped, reward the child and thus contribute to the maintenance of his interest in further exploration of science and its processes.

Accomplishments

The goals of *Science — A Process Approach*, although moderately ambitious, appear to be attainable. What evidences are there, at the present time, that progress is being made toward these goals? What accomplishments can be described?

A systematic course of study. The instructional materials of *Science — A Process Approach* (Parts A-C, 1967; Parts D and E, 1966; Parts F and G, 1970) provide the basic evidence that a systematic course of study in the processes of science has been developed. Successive exercises in each process build upon earlier exercises in a progressive sequence, while at the same time variations in subject matter are deliberately introduced.

Empirical findings concerning the existence of ordered relationships among the exercises, in the sense that successful completion of one contributes to the learning involved in a subsequent one, have been described in reports of the results of pupil testing (*Newsletter*, 1967, Volume 3, No. 3; *An Evaluation Model and Its Application*, 2nd Report, 1968). Additional findings have been obtained, and are to be reported, by administering an individual test of performance in the various processes (*The Process Instrument*, 1969) to groups of children who have participated in the program for one or more years. In general, with some notable exceptions, it has been shown that achievement of lower levels of development in each process increases the probability of attaining subsequent steps in

these intellectual skills. As for the exceptions, these have led to a re-examination of the exercises and the sequencing of developmental steps; and in many instances the latter have been reordered as reflected in the most recent Process Hierarchy Chart (1967).

Continued revision for improvement. From the outset the materials of *Science — A Process Approach* have been subjected to periodic improvement based upon information collected during tryouts in 15 school systems located in various parts of the country. Reports from teachers have provided systematic information on the ease of teaching, technical difficulties, degree of pupil enthusiasm, appraisals of pupil understanding, and related matters. Measures of competence administered to children upon the completion of each exercise have yielded data on the proportion of children achieving each of the defined objectives of the exercise. The target has been to have 90% of the children achieve 90% of the objectives. Each revision of the exercises, in four successive years for each part, has been based upon these findings regarding pupil achievement and teacher reception; and each revision has approached more closely the stated goals of the program. Comprehensive accounts of the information yielded by these two sources of data have been reported (*An Evaluation Model and Its Application*, 2nd Report, 1968).

Broad coverage of science. The booklets of *Science — A Process Approach* exhibit the varied coverage of the fields of science which reflect the aims of the program. The distribution of content in relation to acepted categories of science is approximately as follows Physical Science, 40%; Life Science, 25%, Mathematics, 18%; Earth Sciences, 10%; Social and Behavioral Sciences, 7%. An account of content coverage in biology has been described by Kurtz (1967). Livermore (1966) has made an analysis of the content in the field of chemistry, and Mayor (1967) has given a description of the mathematics content.

Available teacher performances. Another notable accomplishment of the program has been its concerted approach to the problem of orienting and educating teachers of elementary science. The need for materials for the education of teachers was recognized early, and much effort has been devoted to the preparation of a course and accompanying materials for the teacher who is preparing to teach the program. Emphasis is given in teacher education to the science processes and their relation to human intellectual development, in addition to helping teachers acquire the competencies included in *Science — A Process Approach* for application in the classroom. The *Commentary for Teachers* is actually much more than a commentary, for it contains carefully prepared self-instructional lessons relevant to each of the processes. The materials have been tried out and evaluated in several teacher workshops; and their latest form reflects revisions based upon systematic information collected within these sessions (to be reported later in an issue of the AAAS Commission on Science Education *Newsletter*).

Still another product of development is a guide intended for the leaders of sessions for teacher education, reflecting the science processes, their psychological bases, and the variety of science activities and teaching strategies to which they lead. The *Guide For In-service Instruction* (1967) incorporates brief instructional films, self-instructional booklets, and tests for diagnosis and evaluation of teacher learning.

Student achievements. Reports of results on program evaluation (*An Evaluation Model and Its Application*, 1968; *Newsletter*, 1967, Volume 3, No. 3) generally provide much favorable evidence regarding student achievements. For example, it has been found that immediate achievement measures indicate 90 percent of the children to have acquired at least 70 percent of the desired competencies for 97 of 102 exercises in Parts A through D. Further, 90 percent of the children reached the 80 percent level of achievement for all but fourteen of these exercises. When children who had participated in the program for one year were compared with children at the same grade level who had participated for three years, differences favoring the latter group ranged from two to twenty percent. When achievements of a group of children from a low socio-economic background were compared with those of medium and high levels of family income, it was found that although the former group completed fewer exercises, their success on the completed exercises was as high as that of the other children.

Other evidences of the effects of the program have yet to be gathered. More information will be sought on the lasting effects of this program. Answers are needed to such questions as what children know and what they are able to accomplish at the end of the fourth grade, the fifth, and the sixth, after having completed several years of *Science — A Process Approach*. In addition, it is hoped that evidence can be obtained of increased

pupil interest in science, as well as an increased degree of the children's positive valuation of scientific activities after participation in the program over a period of several years.

Expectations

What will a "graduate" of *Science — A Process Approach* be like? What will he know? What will he be able to do? These questions, of course, cannot be answered at the present time with any great degree of assurance. The evidence of what these children are like will have to come, after a period of years, from evidence of what they can accomplish in grades subsequent to the sixth. Perhaps also it will come from evidence of how they behave toward science in even later periods of their lives.

The following descriptions of what may be expected of a child who has completed the program are speculative, although stated in concrete terms. They represent goals which have given implicit guidance to the development of *Science—A Process Approach*. While the full attainment of these goals is greatly to be desired, even partial attainment would surely be viewed as a substantial indication of the program's effectiveness.

1. He will tend to apply a scientific mode of thought to a wide range of problems, including social ones, distinguishing facts from conjectures and inferences, and identifying the procedures required to obtain verification of hypotheses and suggested solutions.
2. He will be able to acquire an understanding of the structure of those particular scientific disciplines he pursues in junior and senior high school more rapidly and with less difficulty than is the case with students today.
3. In a printed account of a scientific experiment, using terms that are understood or defined, he will be able to identify the question being investigated; the variables manipulated, controlled, and measured; the hypothesis being tested; how such a test relates to the results obtained; and the conclusions which can legitimately be drawn.
4. In an oral account of a scientific experiment, given by a scientist using terms intended for laymen, he will be able to identify those elements of scientific procedure and findings mentioned in 3.
5. In an incomplete account of a scientific experiment, such as might appear in a newspaper, he will be able to infer, where necessary, the question being investigated and the elements of scientific procedure described in 3.
6. Given a problem amenable to scientific investigation, and within his understanding as to factual content, he will be able to design (and under certain conditions, carry out) one or more experiments to test hypotheses relevant to the problem.
7. He will show his appreciation of, and interest in, scientific activities by choices made in reading, entertainment, and other kinds of leisure-time pursuits.

To those who have developed the program, these predictions seem not unreasonable. They are things that should happen. If and when they do, the truly important outcomes of *Science — A Process Approach* will be known.

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Science: A Process Approach II (SAPA II)

In 1974, as per the original National Science Foundation contract, the original SAPA program materials became public poperty and Ginn-Xerox lost its copyright privileges. It was at this point in time that the Xerox Corporation released, for elementary school use, a revision of the SAPA program. It is called Science: A Process Approach II (SAPA II). Although SAPA II was developed by Ginn-Xerox, the only company which now sells the program is Delta Education, Inc.

The similarities of SAPA II to SAPA are many. Both programs are still predicated on a behavioral hierarchy. Both were field tested with children. They are both oriented around behavioral objectives and the goal of each is the same, i.e., proficiency in the thirteen intellectual processes. Both are experiential and inductive programs. Equipment and teachers' manuals are supplied with both. Both use strong evaluative techniques. What, then, is/are the difference(s) between the two programs?

The main difference lies in the greater flexibility of the SAPA II program. Design changes in the SAPA II curriculum have attempted to increase flexibility in teaching procedures. Materials are packaged in a continuum of 105 "quasi" ungraded modules (lessons). Each module contains a teacher instruction booklet and various combinations of laboratory hardware, worksheets, spirit duplicating plasters and non-consumable student booklets. In essence, the modules being "quasi" ungraded allows them to be used at various grade levels. There are modules which are classified as "key" or necessary clusters which are the basic prerequisite lessons for any one grade level. After teaching the "key" cluster, however, the teacher may select from a variety of alternative modules as suits his/her purpose. In this manner, the program developers have attempted to build in greater flexibility in the teaching hierarchy than that found in the original program.

A lesser difference is SAPA II's attempt to individualize the program. Latent image worksheets were created especially to help individualize some activities. These sheets, reproduced from special spirit duplicating masters, contain not only questions and space for student comments, but also responses which remain invisible until the lesson is complete and the sheet is rubbed with a special marker. The images then appear on the sheet, and students can check their own work and benefit from the immediate feedback thus provided. It is interesting to note that the above technique increases the dependency of the child on his own reading ability--something which the original program did not necessitate.

Though some of the program components of SAPA II are different, the majority of lesson topics remain essentially the same as those used in SAPA. Some new modules which focus on environmental science applications of process have been added. On the following two pages is a listing of the 105 SAPA II modules and the intellectual process covered by each.*

* This listing was taken from Science . . . A Process Approach II, The Modular Science Curriculum, The Architecture of a Revision by Ginn and Company, a Xerox Education Company, Publication No. M16921.

THE 105 MODULES OF SCIENCE . . . A PROCESS APPROACH II

In graded schools, modules 1 through 12 or 1 through 15 usually constitute Kindergarten, 13 through 24 or 16 through 30 constitute Grade 1, and so on, in groups of 12 to 15 modules per year.

Module Number	Module	Process
1	Perception of Color	Observing/a
2	Recognizing and Using Shapes	Space/Time/a
3	Color, Shape, Texture, and Size	Observing/a
4	Leaves, Nuts, and Seashells	Classifying/a
5	Temperature	Observing/c
6	Direction and Movement	Space/Time/b
7	Perception of Taste	Observing/d
8	Length	Measuring/a
9	Sets and Their Members	Using Numbers/a
10	Spacing Arrangements	Space/Time/c
11	Listening to Whales	Observing/e
12	Three-Dimensional Shapes	Space/Time/d
13	Numerals, Order and Counting	Using Numbers/b
14	Animal and Familiar Things	Classifying/b
15	Perception of Odors	Observing/f
16	Living and Nonliving Things	Classifying/c
	Trees in Our Environment	
17	Change	Observing/g
18	Using the Senses	Observing/h
19	Soils	Observing/i
20	Counting Birds	Using Numbers/c
21	Weather	Observing/j
22	Same but Different	Communicating/a
23	Comparing Volumes	Measuring/b
24	Metric Lengths	Measuring/c
25	Introduction to Graphing	Communicating/b
26	Using a Balance	Measuring/d
27	Pushes and Pulls	Communicating/c
28	Molds and Green Plants	Observing/k
29	Shadows	Space/Time/e
30	Addition Through 99	Using Numbers/d
31	Life Cycles	Communicating/d
32	A Terrarium	Classifying/d
33	What's Inside	Inferring/a
34	About How Far?	Measuring/e
35	Symmetry	Space/Time/f
36	Animal Responses	Observing/l
37	Forces	Measuring/f
38	Using Graphs	Predicting/a
39	Solids, Liquids, and Gases	Measuring/g
40	How Certain Can You Be?	Inferring/b
41	Temperature and Thermometers	Measuring/h
42	Sorting Mixtures	Classifying/e
43	A Plant Part That Grows	Communicating/e
44	Surveying Opinion	Predicting/b
45	Lines, Curves and Surfaces	Space/Time/g
46	Observations and Inferences	Inferring/c
47	Scale Drawings	Communicating/f
	A Tree Diary	Communicating/g
48	The Bouncing Ball	Predicting/c
49	Drop by Drop	Measuring/i
50	The Clean-up Campaign	Predicting/d
51	Rate of Change	Space/Time/h
52	Plants Transpire	Inferring/d

Module Number	Module	Process
53	The Suffocating Candle	Predicting/e
54	Static and Moving Objects	Measuring/j
55	Sprouting Seeds	Observing/m
	Magnetic Poles	Observing/n
56	Punch Cards	Classifying/f
57	Position and Shape	Communicating/h
58	Liquids and Tissue	Inferring/e
59	Metersticks, Money and Decimals	Using Numbers/e
60	Relative Motion	Space/Time/i
61	Circuit Boards	Inferring/f
62	Climbing Liquids	Controlling Variables/a
63	Maze Behavior	Interpreting Data/a
64	Cells, Lamps, Switches	Defining Operationally/a
65	Minerals in Rocks	Interpreting Data/b
66	Learning and Forgetting	Controlling Variables/b
67	Identifying Materials	Interpreting Data/c
68	Field of Vision	Interpreting Data/d
69	Magnification	Defining Operationally/b
70	Conductors and Nonconductors	Formulating Hypotheses/a
71	Soap and Seeds	Controlling Variables/c
72	Heart Rate	Controlling Variables/d
73	Solutions	Formulating Hypotheses/b
74	Biotic Communities	Defining Operationally/c
75	Decimals, Graphs and Pendulums	Interpreting Data/e
76	Limited Earth	Interpreting Data/f
77	Chemical Reactions	Controlling Variables/e
78	Levers	Formulating Hypotheses/c
79	Animal Behavior	Formulating Hypotheses/d
80	Inertia & Mass	Defining Operationally/d
81	Analysis of Mixtures	Defining Operationally/e
82	Force & Acceleration	Controlling Variables/f
83	Chances Are	Formulating Hypotheses/e
84	Angles	Interpreting Data/g
85	Contour Maps	Interpreting Data/h
86	Earth's Magnetism	Interpreting Data/i
87	Wheel Speeds	Interpreting Data/j
88	Environmental Protection	Defining Operationally/f
89	Plant Parts	Defining Operationally/g
90	Streams & Slopes	Interpreting Data/k
91	Flowers	Defining Operationally/h
92	Three Gases	Formulating Hypotheses/f
93	Temperature and Heat	Defining Operationally/i
94	Small Water Animals	Controlling Variables/g
95	Mars Photos	Interpreting Data/l
96	Pressure and Volume	Experimenting/a
97	Optical Illusions	Experimenting/b
98	Eye Power	Experimenting/c
99	Fermentation	Experimenting/d
100	Plant Nutrition	Experimenting/e
101	Mental Blocks	Experimenting/f
102	Plants in Light	Experimenting/g
103	Density	Experimenting/h
104	Viscosity	Experimenting/i
105	Membranes	Experimenting/j

Experiencing the SAPA Strategy

At this point in time, each methods student will be given a set of experiences which will familiarize him/her with Science: A Process Approach (SAPA and SAPA II). Said experiences will include the inspection of teacher booklets at two or more levels, K-6. Further, interaction will be permitted between methods students and materials kits prepared for use with SAPA. Also, instruction in the use of The Planning (Hierarchy) Chart (Xerox) will be followed by detailed investigation of the process hierarchy.

Following these activities, all students will participate in activites from one or more units from SAPA in order that they may experience the program from the child's perspective. The initial laboratory unit experience will be with a Part D (third grade) unit entitled Predicting 4 - The Suffocating Candle (P4). P4 should be located on The Planning (Hierarchy) Chart and its place in the hierarchy analyzed. The Suffocating Candle lesson is used in both the SAPA and SAPA II program.

What follows is a set of information and worksheets appropriate for P4. All asterisked (*) materials are taken directly from the teacher's booklet and are reprinted here with the permission of the AAAS Commission on Science Education, 1973.

THE P4 LABORATORY

Please follow all verbal instructions carefully during the completion of the P4 laboratory. Try to analyze this unit from both a methodological standpoint and a third grader's perspective.

Objectives of P4*

At the end of this exercise the child should be able to

1. CONSTRUCT predictions based on a series of observations that reveal a pattern.
2. CONSTRUCT a revision of a prediction on the basis of additional information.

Rationale for P4*

This exercise illustrates the use of the term prediction in the context of a simple scientific inquiry. Often, the scientist reasons from past or present experience in order to predict the results of a future trial of some event from many partial data. The outcome of the event will then either confirm or refute that prediction.

There are several aspects of the process of predicting that should be recognized. For example, the outcome of an event may confirm a prediction accidentally. To help insure against this possibility, the scientist repeats his tests. Although it is possible to obtain identical results accidentally, the probability of such an occurrence is very low.

When a test is repeated and the result is different, the scientist may infer that not all the conditions in both tests were the same. He then needs to evaluate these conditions to determine whether all conditions were in fact the same, or whether some were different or he overlooked some significant condition. The nature and importance of experimental error is thus emphasized.

Even a prediction that is not borne out by a test can be valuable, and it should not be dismissed too quickly. For example, it can be useful to explore the basis for the prediction more fully. The scientist may have emphasized one piece of his observational evidence at the expense of some other important parts, or he may simply have made a mistake in his analysis. Such a prediction can also point out the need for new observational evidence.

In the activities of this exercise, the children will first observe a burning candle that is covered by a glass jar. They will then predict whether the burning time will be longer or shorter with a smaller jar. Then, on the basis of measurements of both the jar volume and the burning time, they will make more precise predictions of burning time. Finally, they will compare the validity of predictions of burning time. Finally, they will compare the validity of predictions based on interpolation with those based on extrapolation of the data on a graph.

Vocabulary for P4*

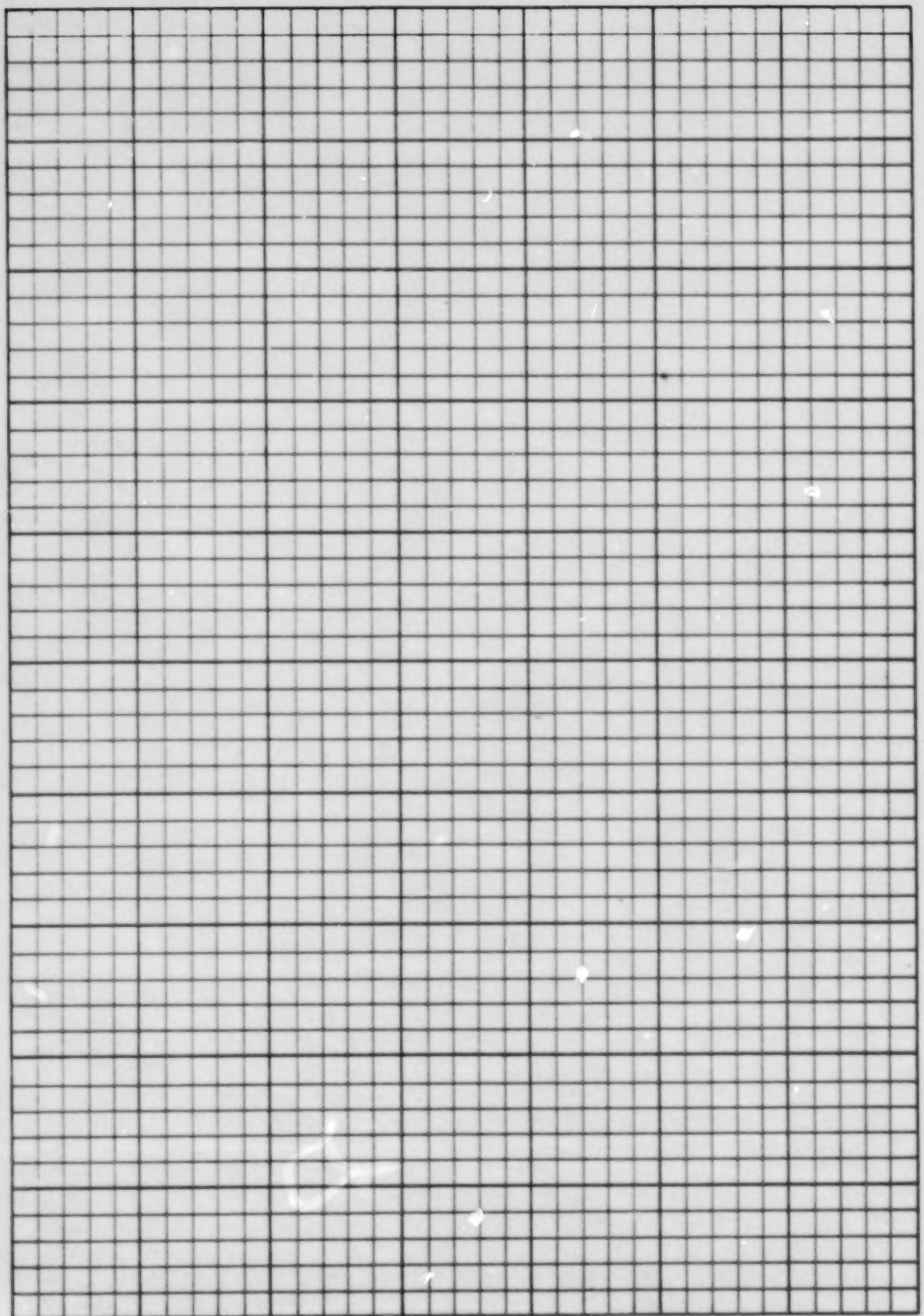
experimental error

interpolation

extrapolation

Data Collection Sheet - Predicting 4 - The Suffocating Candle

Jar	Jar Volume	Predicted Burning Time	Burning Time (Seconds) Trial 1	Trial 2	Trial 3	Mean Time - $\bar{x}$
C		XXXXXXXXX				



Appraisal for P4* Give each group of children a tall, narrow jar, and ask the groups to predict the burning time of a candle under this jar. Ask, HOW WOULD YOU DO THIS? They should suggest making the volume measurement using their arbitrary standard, the smallest jar. Ask them to make the volume measurement of this jar and then to predict the burning time. They should predict from their graphs. If they do not, ask them specifically to use their graph to make another prediction. Then ask them to carry out the test to determine the burning time. Check to see whether they make the measurement two or more times, rather than just once, and whether or not they report a mean burning time. Then ask them to compare their observed mean burning times with their predictions. Also ask whether they have interpolated or extrapolated and how they would interpret the results.

Competency Measure for P4* (Note: The P4 Competency Measure Worksheet found on the next page is for methods students use. It has been designed specifically for this purpose by the authors.)

Competency Measure

TASKS 1, 2, (OBJECTIVE 1): Give the child a sheet of paper with the following table of data or put the data on the chalkboard.

Number Of Ice Cubes	Melting Time (minutes)
4	20
8	60

Now say, "I am going to describe a simple test. Two jars of the same size and shape were half-filled with water. Four ice cubes were added to one jar, and eight to the other. The experimenter then observed that the four ice cubes took twenty minutes to melt, and the eight ice cubes took sixty minutes. Predict how long it will take six ice cubes to melt under the same conditions."

Put one check on the acceptable column for Task 1 (next page) if the child says some time between 30 and 50 minutes.

Then say, "Predict how long it will take two ice cubes to melt under the same conditions."

Put one check in the acceptable column for Task 2 (next page) if he says something less than 20 minutes.

TASK 3 (OBJECTIVE 1): Give the child a copy of the graph shown . . . Point out that the two marked points correspond to the two number pairs in the table.

P4 Competency Measure Worksheet

Competency Measure for Lesson: Part D - Predicting 4 - "The Suffocating Candle":

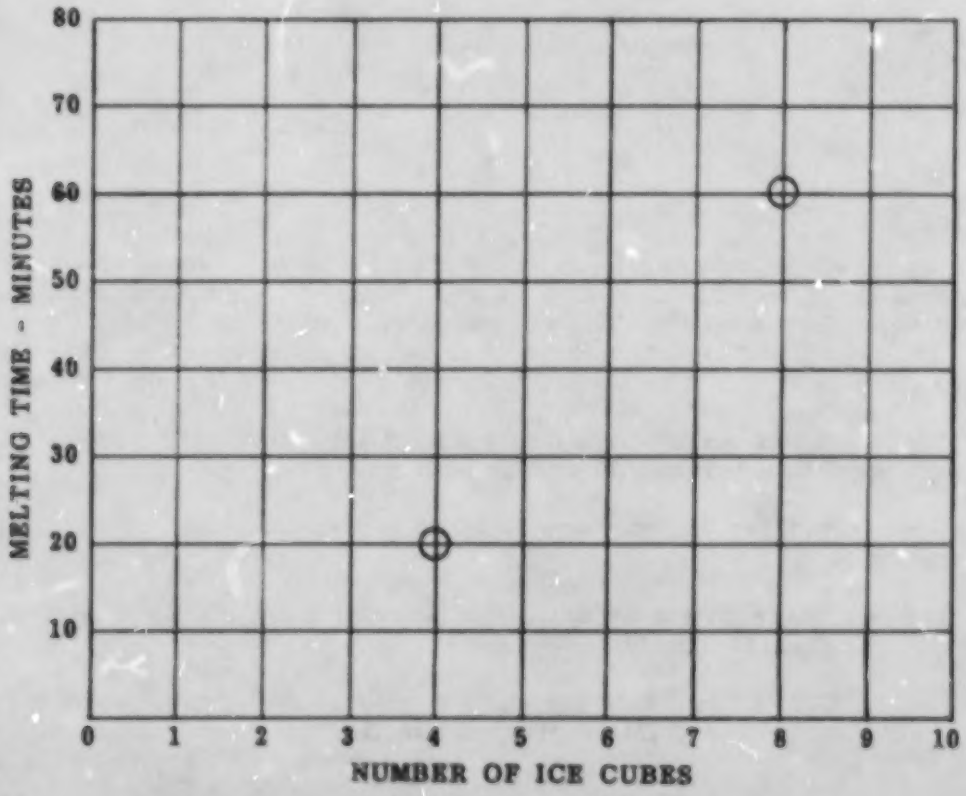
OBJECTIVES:

1. . . . to CONSTRUCT predictions based on a series of observations that reveal a pattern.

2. . . . to CONSTRUCT a revision of a prediction on the basis of additional information.

NUMBER OF ICE CUBES	MELTING TIME IN MINUTES
4	20
8	60

TEACHER'S RECORD		
T	ACCEPTABLE RESPONSE	UNACCEPT-ABLE RESPONSE
1		
2		
3		
4		



(If necessary, use a colored pencil to make the location of the points clear.) Give the child a ruler and a pencil and say, "Make an X on the graph to show how long you predict it will take three ice cubes to melt."

Put one check in the acceptable column if he marks an X on the vertical line above 3, somewhere below the 20 minute line.

TASK 4 (OBJECTIVE 2): Now say, "A test was conducted in which two ice cubes were added to a jar like those used before. The jar was half full of water. The melting time was found to be ten minutes." Add these results to the table of data, and put another dot on the graph to show this added information. Ask, "Would you like to change your prediction for the melting time of three cubes?"

Put one check in the acceptable column if he now changes his prediction for the melting time of three ice cubes to a position representing a time of approximately 15 minutes. (If his prediction was already 15 minutes, put a check in the acceptable column if he says "No," meaning that he does not want to change the position of the X.)

After you have completed the competency measure in methods class, think back over the competency tasks. How well did the tasks evaluate the objectives? Why did the tasks use data regarding melting ice cubes rather than candle burning times?

ELEMENTARY SCIENCE STUDY (ESS)

The second major program with which this work text will deal is the Elementary Science Study, published commercially by the Webster Division of the McGraw Hill Book Company. It is probably somewhat erroneous to call ESS a "program" because it is, instead, an assemblage of 56 separate units spanning grades K-9 which were originally intended to supplement an ongoing science program. Even so, many school districts have taken ESS units and have structured them into a basic program for elementary and, sometimes, junior high schools, while other schools (or teachers) have selected only certain units to supplement their programs.

ESS is one of the major science curriculum projects. It was developed at the Education Development Center, Inc. in Massachusetts. Funds for the project were made available from the National Science Foundation. Initial goals of the ESS development project focused on providing new materials and methods for improving existing science programs. The rationale was sound because, when the project was initiated in 1960, science education rarely reflected a meld of science process and product (skills as well as knowledge). ESS was intended to reflect the substantive structure of science per se by permitting students to investigate a number of unique and innovative topics in manners appropriate to science and to the students own intellectual capacities and interests.

The ESS development phase involved over a hundred professional scientists, teachers, and science educators working cooperatively to develop the materials. Materials consisted of teachers' manuals, equipment, supplies, films,

posters, and in a few cases, student data collection sheets. After an idea was turned into an ESS unit, the total unit was taken into classrooms across the United States and tried in the real world of the elementary or junior high school. Each unit received trial testing in at least fifty different classrooms with children from every kind of socio-economic background exhibiting a broad range of intellectual abilities. Problems with units would be isolated, materials revised, and tried again the following year. Units were commercially published only after exhaustive field testing. Children from urban slums, from fashionable suburbs, from small towns and from big cities all over the United States, in advanced, average or remedial classes have used these units successfully. Because they are not book-oriented, ESS units work well with students whose reading skills are poor, as well as those of superior reading ability.

A major emphasis of ESS is putting materials into the hands of the students. Initially, there may be a good deal of "messing about" or play manipulation of materials and the teacher should accept and appreciate the need for some children to get this out of their systems (in fact, during the preservice training of teachers, it has been a common experience for the writers of this worktext to see methods students doing that very thing with ESS equipment). Elementary students eventually can turn from the "messing about" stage to a more organized investigation of their universe based on the potentials inherent in the unit. Children are natural investigators and their curiosity seems boundless. It becomes a matter of channeling that curiosity into inquiry strategies that have personal payoff from a science standpoint. ESS is a collection of units designed to do this. They all reflect the philosophy inherent in the following ancient Chinese proverb ... I hear ... and I forget...I see... and I remember... I do... and I understand.

ESS units are basically independent of each other. There is no hierarchy in which they must be used. This is but one way in which ESS provides maximum flexibility for the teacher. Units are available in physical science, biological science, earth science, and general skills areas. A unit may encompass a few days or continue for several weeks. Further, units are found to be functional for more than one grade level, i.e., a unit could possibly be used in grade two, or three, or four. The very nature of the ESS materials provides this kind of flexibility.

ESS materials are largely open-ended as well as being investigative. What does this mean? It means simply that students normally have an opportunity to make decisions about the direction their investigations will take. In the unit entitled Behavior of Mealworms, for example, students initially observe the mealworm (a beetle larva) in terms of its physical characteristics. Following this, they are stimulated to begin asking questions about the behavior of this organism in ways in which they can find out answers for themselves. A student's curiosity about mealworm behavior will lead to his own inquiry, directed toward getting answers. Different students may investigate a wide variety of behavior phenomena. In this way, they learn some of the fundamentals of scientific inquiry as well as answer questions in which they are personally interested.

The ESS teacher must be a competent one. Further, the teacher teaching ESS must be willing to act as a consultant - to help children ask questions, observe, design experiments, and interpret these experiments. Although the ESS teacher should understand the nature of inquiry and open-ended investigation, he/she must also be prepared to admit that he/she knows not the answer and

take the position that the teacher and the child can learn together. This, surprisingly perhaps, builds respect between student and teacher and creates a classroom atmosphere with considerably more flexibility than that of the traditional classroom.

It would be impossible within the confines of this worktext to describe each of the ESS units. However, the following descriptions of several of the units will help give you a flavor of the ESS unit content and activities.

DESCRIPTIONS OF SOME ESS UNITS

Batteries and Bulbs - Grades 4 to 6: An introduction to the study of electricity and magnetism. Each child carries out activities with simple and safe equipment - flashlight batteries, small bulbs, various kinds of wire, magnets, and a compass - and draws conclusions and makes inferences based on his/her observations.

Light and Shadow - Grades K-3: In their exploration of light and shadows, children find new meanings in a number of ordinary objects and phenomena. They use many shapes and their own movements to examine light sources and the shadows they cast. An opportunity is given for young children to experiment with spatial relationships in simple ways.

Match and Measure - Grades K-3: This resource book suggests interesting activities for primary children to learn about measurement in an informal way, using measuring sticks, tape measures, calipers, measuring wheels and a Geo board.

Structures - Grades 2 to 6: Children love to build things, and in this unit they discover through trial and error that the physical and aesthetic properties of the materials used in building determine to a large extent the size and strength of a structure, as well as how interesting it is. Some of the materials used for building are paper, index cards, straws, modeling clay, wood scraps, cardboard, and spaghetti.

Microgardening - Grades 4 to 7: This unit deals with the growth of a microorganism, namely mold. The children identify variables that influence mold growth and design experiments to test for these factors. In doing this, they become aware of the diversity of color, texture, and structure of molds as well as becoming familiar with some basic scientific procedures. Students are introduced to pure cultures and sterile techniques and become involved in problems that allow them to trace the reasoning of some of the great pioneers in medicine, agriculture, microbiology and food technology.

Attribute Games and Problems - Grades K-9: This unit provides general skill activities for children using a set of hardwood blocks of many shapes and sizes which have been carefully designed to give experience with geometric shape and stimulate interest in linear, surface area and volume relationships. Problem cards which deal with the identification of properties and classification of sets of objects are also included.

Animal Activity - Grades 4 to 6: Children use observation, experimentation and data interpretation skills for examining the behavior of mice, gerbils, and other small animals, noting how diet, age, size of cage, noise and time of day affect the animals' behavior.

Gases and Airs - Grades 5 to 8: The unit is a series of closely linked laboratory experiments investigating the nature of air and the changes it undergoes when interacting with common objects in the environment. Students undertake investigations with the gases of the atmosphere ("air") and the "things" of the universe (rock, iron, water, seeds, and a candle). NOTE: The photograph in this section shows youngsters involved in a Gases and Airs activity).

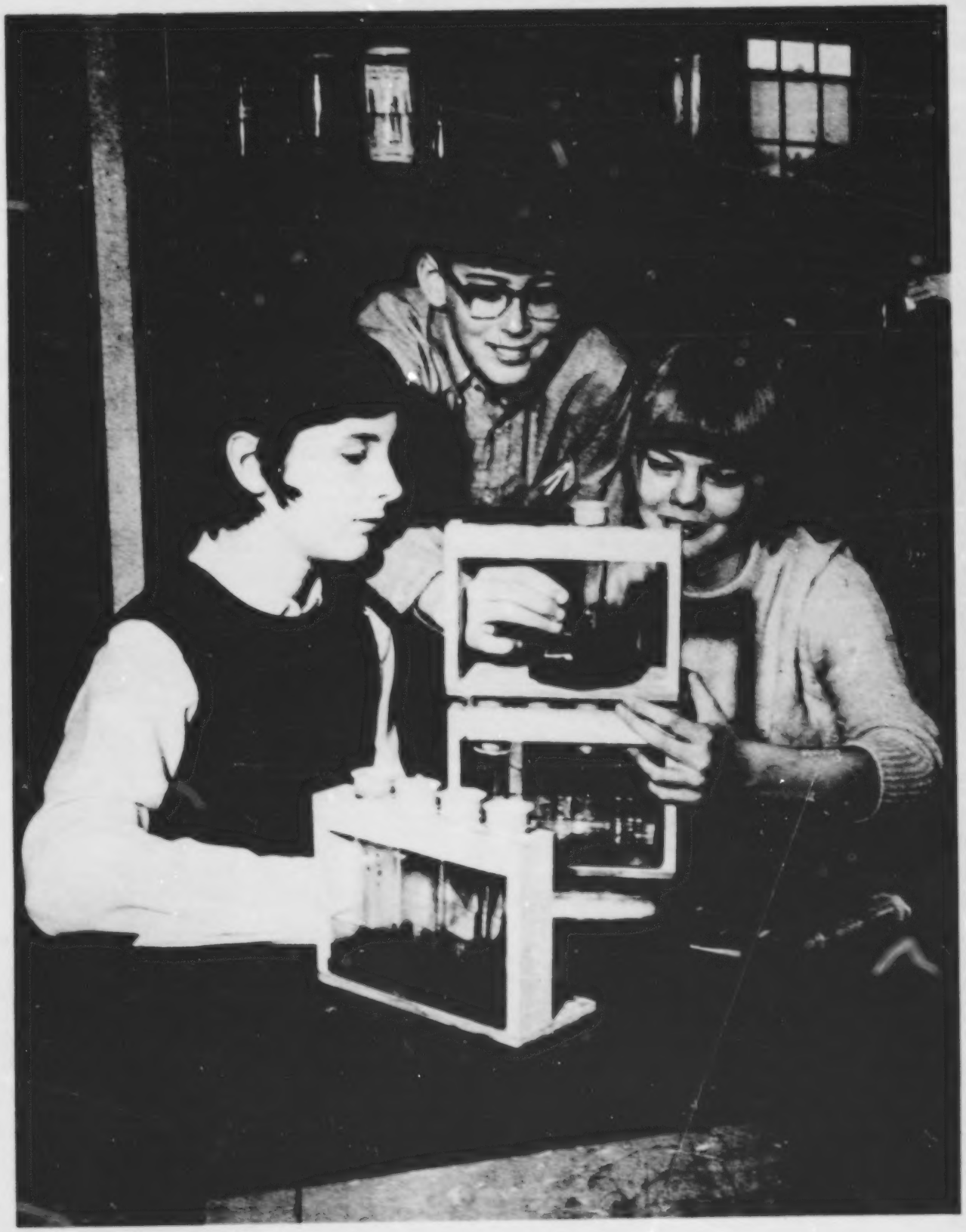
Kitchen Physics - Grades 5-9: The students investigate the properties of some common liquids - water, soapy water, oil, alcohol, and syrup. In laboratory experiments, they consider such attributes of liquids such as how they are absorbed, evaporate, drop, stream, and interact with various surfaces.

Rocks and Charts - Grades 3-6: Children become involved in the classification of some common minerals. As well as discovering the characteristics of the individual rocks, children learn something about setting standards for comparison by developing data records (charts) on which they can compare the attributes of more than one specimen.

How is student progress evaluated in ESS? The people who developed ESS specify that evaluation should be a process that is implicit in the teaching of the ESS unit. This is interpreted as meaning that evaluation is an ongoing process and that appraisals can be provided from direct observation of the student's use of process, his generation of knowledge, and his scientific attitudes. Surely, this is a fundamental aspect of excellent teaching in any well-devised science program.

However, the teacher who desires to make a critical evaluation of student progress in ESS must carefully analyze those tasks with which the child is engaged and construct his own evaluation instrument or task. If a group of students are absorbed in the business of manipulating and controlling variables (as well could be the case in a unit such as Kitchen Physics), the teacher should make the most of the student's progress in the skills of manipulating and controlling variables. Certainly, if the objective is process, the evaluation should be in the process dimension. As the old adage goes, . . . when teaching bananas we must test bananas . . . not oranges . . . or apples . . . or pomegranates! Evaluation must bear a one to one correspondence with what is taught. In ESS, it would be relatively easy to evaluate student learning in a manner not quite consistent with the teaching because many of the processes used can be masked by the knowledge being created.

Of course, all evaluation should not be accomplished simply to evaluate the student. The teacher can also evaluate her teaching style and the effect of the units by observing students engaged in the business of doing science. One important attribute, often overlooked, is the enthusiasm of the students. If it exists, the teacher has accomplished an important objective - "turning children on" to learning!



It should be noted here that the original ESS units became public domain in the early seventies just as the SAPA materials did. At that point in time, McGraw Hill modified the ESS teachers' manuals and incorporated many new teaching suggestions. The manuals now contain listings of the skills and concepts each unit is designed to teach; research projects that can be undertaken; suggestions for integrating the unit's content with mathematics, social studies and language arts; and general teaching strategies. The actual student activities have not changed, for the most part, from the original ESS units.

EXAMPLES OF ESS FLEXIBILITY

ESS Unit	Grade Levels at Which Unit Can Be Used									
	K	1	2	3	4	5	6	7	8	9
Light and Shadow	x	x	x	x						
Match & Measure (Skills Unit)	x	x	x	x	x	x	x	x		
Butterflies	x	x	x	x	x	x				
Geo Blocks (Skill Unit)	x	x	x	x	x	x	x			
Attribute Games & Problems (Skills Unit)	x	x	x	x	x	x	x	x	x	x
Brine Shrimp		x	x	x	x					
Mystery Powders				x	x					
Rocks & Charts				x	x	x	x			
Colored Solutions				x	x	x	x	x	x	
Bones					x	x	x			
Behavior of Mealworms					x	x	x	x	x	
Stream Tables					x	x	x	x	x	x
Gases and Airs						x	x	x	x	

Original ESS units (or portions of the units, e.g., teacher's manuals, individual pieces of equipment, class kits, supplementary reading books) can be purchased from Delta Education, Inc. whereas the modified units (as described above) are available only from McGraw Hill.

Lastly, McGraw Hill has developed an evaluation program for ESS. It gives teachers an easily managed assessment tool with which student achievement may be measured in each of the 56 units without losing the basic, open-ended, flexible nature of the ESS program. There are five goals of the evaluation program. They are: rational thinking processes, manipulation, communication,

concepts, and attitudes. Specific objectives related to each of these goals and to observable student behavior in meeting these objectives are provided in a checklist form for easy use. The evaluation program must be purchased directly from the Webster Division of the McGraw Hill Book Company.

Experiencing the ESS Strategy — At this time, each methods student will be given a set of experiences designed to familiarize him/her with Elementary Science Study (ESS). Said experiences will include a general inspection of several ESS units, i.e., teacher's manuals and equipment.

Further, all students will participate in one or more units from ESS in order that they may experience the program from the child's perspective. Specific instructions will be given in the laboratory for each investigation. Students will be referred to worksheets designed for use with these experiences and incorporated into this section.

An Additional ESS Assignment - Subsequent to these activities, each student will prepare a paper, not to exceed 750 words (3 typed pages) which adheres to the following parameters:

1. Each methods student will choose a particular grade level for a regular elementary school situation OR a particular population of children with special needs (e.g., disadvantaged, educably mentally handicapped) and design a one year science program for that population using ESS units.

2. Each methods student will specify the assumptions made in preparing the design (i.e., grade level, type of student population, student needs).

3. The design must incorporate at least four and no more than seven ESS units. Units must be identified by title, content area (e.g., earth science, general skills), and a succinct summary of the activities.

4. The methods student will communicate the rationale for said design from an educational perspective, i.e., why were these units selected for use with children from a general education standpoint? How will they accomplish the goals of the teacher?

WHAT ARE THE MYSTERY POWDERS?

POWDER NUMBER	WHAT I THINK IT IS	WHY I THINK SO
1		
2		
3		
4		
5		
6		

Methods Worksheet for Mystery Powders (ESS)

SCIENCE CURRICULUM IMPROVEMENT STUDY (SCIS)

The third major program with which this worktext will deal is the Science Curriculum Improvement Study (SCIS), commercially handled by Delta Education, Inc. SCIS was developed at the University of California, Berkeley with the help of monies contributed by the National Science Foundation.

The SCIS program effectively combines both the process and product sides of science. In fact, the producers of SCIS proclaim that this product blends the knowledge, skills, and attitudes of science into a functional science program. SCIS differs markedly from the programs described thus far in that its activities focus on a conceptual hierarchy.

The developers of SCIS feel that the conceptual portion of science is crucial and that it can be developed as a function of well-developed activities. Thus, they feel that a science program should be judged on both its experiential base (process component) and the conceptual hierarchy developed as a function of those experiences.

The SCIS program contains twelve units (six in the physical sciences and six in the life sciences) for Grades 1-6. Therefore, each year of the SCIS program finds children experiencing two units of instruction, one in physical science and one in biological science. These can be taught in either order. The major concepts involved throughout the physical science units are matter and energy. The life science units involve concepts regarding the organism and ecosystem. Woven into all these knowledge components is the important idea of interaction, i.e., the relation among objects or organisms that do something to each other and thereby bring about a change. Thus, interaction relationships are stressed as the student's conceptual knowledge increases in sophistication.

The SCIS program has recently added a single unit called Beginnings, which is taught at the kindergarten level. The purpose of this entire year unit is to develop children's powers of observation, discrimination and description. A wide variety of experiences and activities in the life and physical science is used. Through suggested games, puzzles, and other activities, the children develop their abilities to describe and compare objects by their color, shape, size, texture, odor and sound. The concepts of number and volume are introduced. The experiences in this unit contribute to a growing understanding of science and to language development. The chart found on the next page names the units of the SCIS program, gives an overview of the content in each unit and identifies the major concepts taught in each unit.

Philosophically, the developers of SCIS state the overall objective of the program to be scientific literacy. Said literacy is achieved as a function of the meld of process experience, attitude formation, and conceptual growth of the child. It should probably be added that the conceptual framework of the program agrees with the perceptions of many educators as to the knowledge that is of considerable importance to all literate human beings. Given the rationality of the decisions concerning content and the success of SCIS in developing this knowledge, the elementary school has a powerful and important science program in this one.

SCIS is inquiry oriented, and, therefore, highly inductive in its learning experiences. For example, in the first grade, children build aquaria with water, sand, plants, fish, and snails. The students observe the aquaria from a number

OVERVIEW OF THE SCIS PROGRAM*

LIFE SCIENCE - CONCEPTS	OVERVIEW/LEVEL	PHYSICAL SCIENCE - CONCEPTS
1 **ORGANISMS** organisms birth death habitat food web detritus	During the first grade, objectives deal with childrens' observational skills - observation, discrimination, and accurate description (communication). These processes are developed as children care for aquatic plants and animals, raise seedlings, and investigate the properties of nonliving objects.	**MATERIAL OBJECTS** object property material serial ordering change evidence
2 **LIFE CYCLES** growth development life cycle genetic identity generation biotic potential plant and animal metamorphosis	The theme of both units is change, observed as evidence of interaction or by the development of an animal or plant. These two units require children to add the mental process of interpreting evidence to the observational skills they developed during first grade. Children work with magnets, batteries, wires, chemicals, photographic paper, pulleys, electric motors, seeds, mealworms, frog eggs, and fruit flies.	**INTERACTION AND SYSTEMS** interaction evidence of interaction system interaction-at-a-distance
3 **POPULATIONS** population predator prey community plant eater animal eater food chain food web	Children observe and experiment with increasingly complex phenomena as they move toward understanding the energy, matter, and ecosystem concepts. In the physical science unit children experiment with solids, liquids, and gases and make and analyze measurements. In the life science unit the children observe the interactions of various organisms within a community of plants and animals considering interdependence.	**SUBSYSTEMS AND VARIABLES** subsystem histogram evaporation solution variable
4 **ENVIRONMENTS** environment environmental factor range optimum range	In the life science unit, children consider for the first time some of the physical conditions that shape an organism's environment. These investigations make use of the measurement skills and scientific background developed in the physical and life science units during the first three years. The physical science unit introduces techniques for dealing with spatial relationships of stationary and moving objects	**RELATIVE POSITION & MOTION** reference object reference frame relative position & motion polar coordinates rectangular coordinates
5 **COMMUNITIES** producer consumer decomposer photosynthesis community	Conceptual development continues as examples of energy transfer are introduced in the physical science unit and of food transfer in the life science unit. Children apply the systems concept, the identification of variables, and the interpretation of data with which they have become familiar during the earlier years of the SCIS program.	**ENERGY SOURCES** energy transfer energy chain energy source energy receiver
6 **ECOSYSTEMS** ecosystem water cycle oxygen-carbon dioxide cycle pollution	The life science unit integrates all the preceding units in both physical and life sciences as children investigate the exchange of matter and energy between organisms and their environment. The physical science unit introduces the concept of the scientific model and thereby opens a new level of data interpretation and hypothesis making. At the same time, the children relate matter and energy to electrical phenomena.	**MODELS: ELECTRICAL AND MAGNETIC INTERACTIONS** scientific model electricity magnetic field

* Adapted from Science Curriculum Improvement Study (a commercial brochure). School Department, Rand McNally and Company, 1970.

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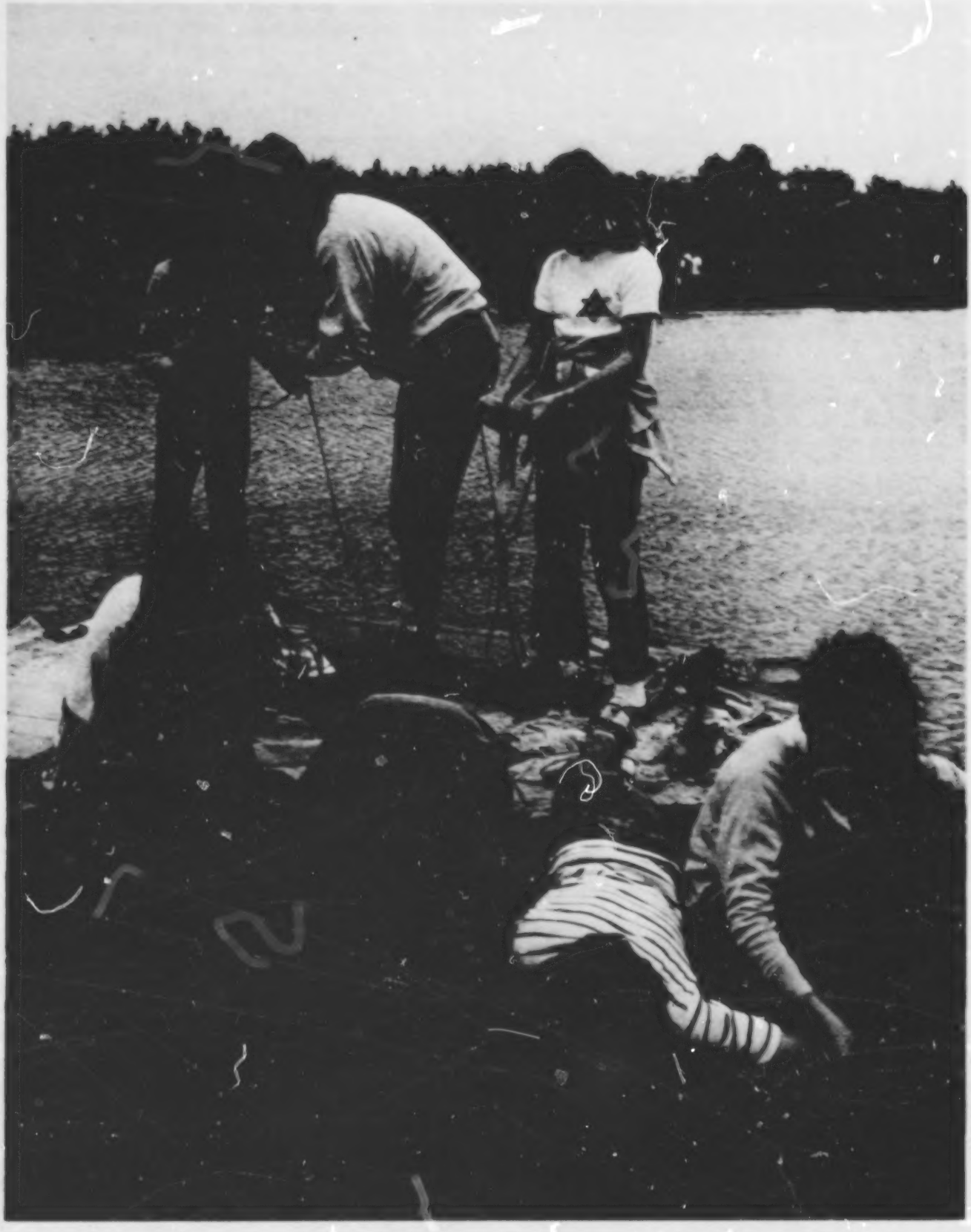
of different perspectives. In a few weeks they notice that a black material has accumulated on the sand in the aquaria. The students' curiosity leads them to wonder what this black "stuff" is and where it came from. Traditionally, the teacher would tell the children that this black material is called detritus and that it originated with the death and decay of animals and plant parts and the wastes of living organisms. Here it would probably end. In SCIS, however, the children pose hypotheses to account for the origin of detritus and set up experiments to test their hypotheses. Later they compare the growth of seeds in sand to which detritus has been added with growth in sand lacking detritus. Not only do children get a good concept of detritus, but more importantly they begin to perceive the interactions that take place between organisms and between organisms and their abiotic (non-living) environment. They also receive experiences with intellectual processes such as observation, hypothesizing and experimentation.

Interestingly, SCIS does not rely solely on the laboratory experience for learning and sustaining learning. At various times in the program, field trips are utilized to help facilitate conceptualization. Numerous out-of-class activities lend themselves well to the conceptualization of such ideas as habitat, population, community, plant eater, environment, producer, ecosystem, and pollution. Similarly, discussions are promoted between children and between teacher and children. The discussion might be initiated by the teacher utilizing divergent questions to stimulate a variety of student responses. Or, if the teacher desires to check on the acquisition of knowledge, convergent questions may be used. Children can go to books to gain more information on a number of topics. However, success in SCIS is not predicated on a child's ability to read because the child can always turn to the real three-dimensional world in which he lives for information. Once again, we find a science program suitable for a wide range of student ability levels. In fact, it was observed during extensive use in urban, rural and suburban schools that the earlier editions of the units proved to be particularly helpful as part of the overall effort to improve children's oral language skills. The same potential exists with the current edition. The experience with real and interesting materials is especially effective in the case of disadvantaged or deprived children whose desire to speak and participate in class discussions increases dramatically.

The SCIS teaching format is not organized into tightly structured lessons. Rather, a unit is composed of several parts, each having specific behavioral objectives. The parts, in turn, are divided into chapters. Each chapter may contain several activities as well as suggestions for optional, extension lessons.

The SCIS program uses a specific instructional strategy which is based on the Piagetian theory of intellectual development. The strategy is called The Learning Cycle (which is discussed in depth in Part IV). The Learning Cycle has three stages, namely exploration, invention and discovery which reflect a sound inductive pedagogical approach to concept formation.

In the exploration stage, students do just that, i.e., children learning through their own spontaneous behavior by investigating and examining objects and events with minimal guidance in the form of teachers' instructions or specific questions. The materials the children explore have been carefully chosen to be easily used and to generate certain questions that the children have not asked before. For example, students may make observations regarding the behaviors of crickets and a chameleon which have been placed in a grass-filled terrarium. They observe that much of the grass disappears and that the number of



crickets decreases over time. This set of observations may generate questions such as: What happened to the grass? Where did the crickets go? Did the chameleon have anything to do with the disappearances? These observations and questions provide the intellectual framework for the next stage in the learning cycle - Invention.

The invention stage serves as the point where the teacher assists the children in interpreting the phenomena they observed during the exploration lesson. The spontaneous learning done during exploration is limited by the child's preconceptions. He/she needs concepts to help interpret and "nail down" his observations. Since few children can phrase new concepts by themselves, the teacher at times must provide a term and a definition for a new concept. In the terrarium example given earlier, the students have the observations necessary to develop the concepts of predator, prey, plant eater, animal eater and food chain. It is during the invention stage that any or all of these concept labels and definitions can be introduced to the child by the teacher. After concept introduction, the teacher can give the children opportunities to use the new concept and encourage them to look for other examples that illustrate the idea.

In the discovery stage which follows invention, students engage in different activities selected to allow them to discern a new application for a concept. Going back to the terrarium example again, the teacher might arrange a field trip during which the children identify other predator-prey relationships. Or, a film which depicts this relationship in variety of settings (e.g. pond, ocean, forest, African grassland) could be shown and discussed by the class. The children's discovery activities (which culminate the learning cycle) reinforce the original concept and enlarge and refine its meaning. In this way, mastery and retention of concepts are aided by practice and repeated, wide application.

One SCIS activity may extend beyond a single class period or several activities may be included in one session. Certain activities, such as the investigation of pulley systems and the magnetic box puzzles are intended for small group or independent study. Other activities are more successful when a larger group or the whole class works together.

Flexibility of the teacher is imperative. So is inservice education of teachers. Successful implementation of SCIS into a total school district is predicated on a successful orientation of teachers to the goals and methodologies of SCIS.

In response to the requests of classroom teachers using the SCIS materials, the developers of the program have produced packets of evaluation materials for each of the twelve units. Each packet contains spirit duplicating masters and specific instructions for evaluating the following aspects of student progress: (1) attitudes in science, i.e., curiosity, inventiveness, critical thinking and persistence; (2) student perception of the classroom environment; and (3) concept/process objectives. Evaluation packets are supplementary to the program and are available from the Science Curriculum Improvement Study, Lawrence Hall of Science, University of California, Berkeley, California 94720.

Use of the evaluation packets is not mandatory for evaluation of student progress. The teacher has the option to use the program's behavioral objectives as a guideline for constructing evaluation measures. Direct observation of student behavior is another available technique. The authors of this worktext would remind any teacher who uses his/her own evaluative measures with SCIS

or any other program to be sure that evaluation bears a one to one correspondence with what is taught!

The SCIS program can be purchased unit by unit, i.e., two units are purchased separately per year. Unit materials contain supplies and equipment, teacher's guide, and student booklets. Replacement packages are available so that the teacher can replace expended materials and student booklets each year. Living plants and animals are also provided by the supplier where needed.

A SCIS Update

The original SCIS program materials became public domain in the mid 1970's. The publisher of those materials at that time, The Rand McNallyCompany, decided to produce a modified version of the SCIS materials. They subsequently published it under the program name, Rand McNally SCIIS. The authors of Rand McNally SCIIS retained the best of the original program - the basic philosophy of the program, the goal of scientific literacy, the conceptual framework in both the life and physical sciences and the learning cycle approach. The changes made included some new activities which seemed more relevant to today's children and science. For example, some earth science activities were added. Also, the developers renamed the 6th grade physical science unit, "Scientific Theories", although little change was made in the unit's activities.

The most drastic changes are in the equipment, the teacher's manuals and supplementary materials. The teacher's manual now contains the evaluation procedures rather than having them in an independent booklet. Student manuals (i.e., record books) were created for the first three life science units so that all twelve units now have student record texts. Finally, a set of 20-40 activity cards called Extending Your Experience (EYE) cards were created for each unit. The EYE cards can be used for remedial work or for small group or individual student independent study. Rand McNally has turned this program over to Delta Education, Inc. which is now the sole supplier of all of the modern science program discussed in this chapter.

Experiencing the SCIS Strategy -

At this time, each methods student will be given a set of experiences designed to familiarize him/her with SCIS. These experiences will include an inspection of several units, teachers' materials, and evaluation strategies. Further, all students will get direct laboratory experiences with SCIS in order that they may experience the program from the child's perspective. Specific instructions for each investigation will be given in the methods laboratory.

In Summary

You have been introduced to three very different yet somewhat similar models for teaching. SAPA is highly inductive, structured and teacher-directed with the aim of instructing youngsters in thirteen critical thinking skills. ESS is also highly inductive but relatively unstructured with the lessons often taking the direction chosen by the students. Its intent is to introduce students to elements of process and product. SCIS is semi-structured with an inductively approached

conceptual hierarchy. The program addresses skills, attitudes and processes. Regardless of whether you have the opportunity to teach any of these programs, it behooves a teacher to be aware of these various approaches and to apply them where appropriate as you develop a sound, effective science program for your own classroom.

PART VIII

Science Textbooks: Analyzing and Modifying Them for Use in the Classroom

Performance Objectives

Subsequent to your interaction with this part of the worktext, you will be expected to be able to. . .

1. . . . compare each of the Project Synthesis goal clusters against frequently used textbooks (and NSF-sponsored programs such as ESS and SAPA) and communicate how well they meet the goals in question.

2. . . . describe specific mechanisms that can be employed by the elementary teacher who is using a textbook series to make certain that at least some of the Project Synthesis goals can be covered. Similarly, describe how these strategies should be used to facilitate scientific literacy.

3. . . . explain why a school district should have its science education goals sharply in focus before attempting to choose a science textbook program. (In other words, this infers that texts vary - and, they do! Know how they vary and how this could relate to the philosophical setting of the school district. For example, consider such potentially controversial topics as reproduction and evolution and how these topics are presented.)

4. . . . describe how textbooks differ in terms of whether activities promote inductive or deductive learning. Make certain that you can explain the differences you would have to observe to determine whether the learning was inductive or deductive in nature.

5. . . . cite several examples of characteristics one should look for in a Teacher's Guide in a science textbook series and explain why these characteristics are of significance to the teacher.

6. . . . describe, citing specific attributes, the ideal science textbook for use in the elementary school. Defend your description in terms of scientific literacy and teaching effectiveness.

7. . . . (on the basis of your own textbook analysis) develop a chart which lays out both stengths and weaknesses of elementary science textbooks. Be prepared to defend your selection of strengths and weaknesses.

Science Textbooks: Analyzing and Modifying Them for Use in the Classroom

Without a doubt, the science textbook series is the most common vehicle used for the teaching of science in the elementary school classroom. This fact could easily infer that science textbooks fulfill the scientific literacy goals outlined in Part II of this worktext. How accurate an inference is this?

Rather than give a simple yes or no answer to the question of textbook effectiveness, the writers will let you make up your own mind. In order to do this, you will need some further information.

You will recall the goal clusters identified by Project Synthesis (in Part II of your worktext). One of the Project Synthesis team's task was to compare the goal clusters against commonly used science textbooks at the elementary school level to determine the extent to which they fulfilled the goals of Project Synthesis. At the same time, they took a look at the NSF-sponsored programs (i.e., ESS, SCIS, and SAPA) to see how well they corresponded with Project Synthesis goals.

Below, you will find a chart which displays some of the Project Synthesis team's findings. Each goal cluster is presented along with some of the possible subgoals identified by the team. Congruence between the subgoals and frequently used texts and the NSF-sponsored programs is rated. (Adapted from What Research Says to the Science Teacher, Vol. III (Harms and Yager, Eds., 1981, pps. 79-81).

Congruence of Frequently Used Texts and NSF-Sponsored Programs With Example Project Synthesis Subgoals

GOAL CLUSTER I: Personal Needs.

Possible Subgoals	Congruence: Frequently Used Texts	Congruence: NSF-Sponsored Programs
1. Consumer Behavior	None	None
2. Personal Health Information	High-Good	Low
3. Skills in Gathering Information	None	High
4. Decision-Making	None	Good

GOAL CLUSTER II: Societal Issues.

1. Solutions Can Create New Problems	None	Slight

Congruence Chart (Continued):

Possible Subgoals	Congruence: Frequently Used Texts	Congruence: NSF-Sponsored Programs
2. Decision-Making and Community Consequences	None	Good in SCIS
3. Ways Science Changes Lifestyles	None	Slight
4. Sense of Custodianship	None	Slight
GOAL CLUSTER III: Academic Preparation.		
1. Skill Development	None	High
2. Variety Based on Student Interest	None	Low-High Depending upon Program
3. Coverage of Scientific Concepts, Laws, and Theories*	Good-High*	Slight-Good Depending upon the program*
4. Respect for Empiricism*	Low*	High*
GOAL CLUSTER IV: Career Awareness		
1. The Human Side of Scientists	Low	Low-None
2. Minority Access to Careers	Low	None
3. Making Informed Career Decisions*	None*	None*
4. Obtaining Further Information on Careers*	Low-None*	None*

* These are subgoals and assessments added by the writers in order to provide additional information in which the methods student would most likely be interested.

Now, back to the original question. How well do frequently used science textbooks stack up against Project Synthesis goals? Using the information on the chart above, write a succinct statement which represents your evaluation of the congruence between texts and Project Synthesis for each of the four goal clusters.

My Evaluation of Congruence

It appears, from the information presented, that science textbooks don't stack up well against Project Synthesis goals (for the most part). Sure, there are some things that science textbooks do very well and we will not argue that. But, in terms of their providing for scientific literacy, they appear to fall short in many critical areas.

The question becomes one of whether there is anything that you as a teacher can do to improve on the literacy potential if you are forced into using a science textbook series. The answer is "yes". There are a number of strategies that you can use to improve upon the typical textbook in terms of your own overall instructional program.

Strategies for Using the Textbook for Literacy

Below, you will find listed a number of sound suggestions for teaching for literacy if you are using a textbook program in your school. Although the discussion of these strategies may be brief, they should be taken with the utmost seriousness. An appropriate meld of these methods will greatly enhance your helping your students achieve scientific literacy.

1. INFUSE LOCALLY SIGNIFICANT SCIENCE-RELATED SOCIAL ISSUES INTO YOUR SCIENCE PROGRAM.

This particular strategy is particularly pertinent to the Societal Issues Goal Cluster of Project Synthesis. Issues of this type would include those that relate to medicine, business and industry, population density pressures, land-use management, sewage disposal, solid-waste management, zoning, etc.

Regardless of the sensitivity of the issue, children should have an opportunity to explore the various sides of the issues, debate the solutions, and become knowledgeable about what is happening in the socio-scientific world surrounding them. Do not hesitate to provide this opportunity although your teaching posture should be value-fair, i.e., you should not attempt to superimpose your own values on the students. (Note: An entire chapter of this worktext deals with environmental education and focuses on many of the elements associated with issue investigation and values clarification).

2. USE LOCAL RESOURCES AND RESOURCE PEOPLE IN YOUR SCIENCE PROGRAM.

Far too few teachers are willing or able to make use of community resources in their teaching. In almost all communities - large or small - live people who are more than willing to share their expertise with the children and/or the teacher. Further, there are physical resources in ALL communities (school districts) which are valuable teaching tools.

Some progressive school districts have actually inventoried local/regional resources available to teachers and make these inventories available to every teacher. In other instances, agencies beyond the school itself have inventoried resources which have educational significance. In some cases, these inventories are produced as manuals; in other cases these resource inventories are computerized. In some situations, teaching staffs have received training in the use of those inventories. This training has been shown to be extremely effective.

Using the community/region as a profitable part of the science program can pay rich dividends. Resource people can help tremendously in the career awareness phase of your program or to help make science concepts become more meaningful. Similarly, visiting a hardwood forest or a desert or a swamp or a zoo, etc. can make the textbook come alive if appropriate strategies are employed. Further, and equally or more important, is the fact that many community resources will permit instruction on literacy components which are ignored by or absent in the text.

3. FOCUS ON THE PROCESSES INVOLVED IN SCIENCE ACTIVITIES (AS WELL AS THE CONCEPTS).

One of the major weaknesses of many textbook series is that they talk about the development of process without really doing it. During a science activity, students need to know what kind of mental activity they are engaging in. This will help them develop the skill further. If a science activity involves a good deal of observation, discuss the elements of scientific observation before the activity so that students can practice the skill knowing precisely what it is

they are doing. The same would hold true for any other process, e.g., inferring, data interpretation, experimentation. This will, in no way, interfere with the acquisition of the desired conceptual content. In fact, it may enhance it.

4. GENERATE PROCESS DEVELOPMENT ACTIVITIES IF CERTAIN SKILLS ARE NOT COVERED IN THE TEXT.

Oftentimes, it is obvious that students will not have an opportunity to develop particular science process skills even though there may be numerous activities in the text itself. For example, in many instances, there is no true experimentation in the science textoook (regardless of what the activities may say in their titles). Certainly middle school students can and should learn the rudiments of true experimentation. At times, activities for the sake of process acquisition per se are called for. How does one accomplish this?

There are often many ways to go about setting up scientific experiments which correlate well with the text's content. This takes a bit of creative thought on the part of the teacher. Most certainly, if process acquisition is important, it is not crucial that the process activities correlate with existing curricular content. Examples of such activities can be found in this methods book. Most, but all, will be found in the chapter dealing with science process. Use them as they are or modify them for use with your age group. Many more ideas can be gleaned from SAPA, ESS, or SCIS teachers' guides.

5. DON'T BE LIMITED BY A LACK OF COMMERCIALLY PREPARED EQUIPMENT.

Far too often, teachers will say, "I can't do activities with my children because I don't have the equipment and my school district will not provide it." In the opinion of the writers, this is a weak excuse for conducting a "read about science program".

Many, many good elementary teachers have found that, in order to provide a rich, exciting science program for their students, they are going to have to make, beg, borrow, and even purchase some materials. Unfortunately, this is often simply a fact-of-life. You will recall that many of the activities used in this methods book utilized inexpensive and locally-obtainable materials, e.g., candles, matches, rulers, coins, jars of various sizes, graph paper, water, washers. It is beyond comprehension that any teacher can logically argue the inability to obtain these kinds of things.

Even more sophisticated equipment can be constructed by the teacher (or the teacher's sweetheart, husband, or someone else). Examples are the construction of pendulum stands out of inexpensive or scrounged wood, making large aquaria out of plate glass or refrigerator liners (often available in junkyards), terraria out of double strength glass and a heavy binding tape (or even out of large jars - plastic or glass), geometric blocks out of 2 X 4's, etc.

6. KEEP UP ON THE NEWS (TV, MAGAZINES, NEWSPAPERS) AND SHARE SCIENCE EVENTS WITH CHILDREN.

Help students keep up with the growing body of knowledge in science by watching TV and reading science news in periodicals. Although it is NOT recommended, there are so many sources of information on new events in science that

you could structure a science program around this content all by itself. Periodicals such as Newsweek and Time help keep the public abreast of new advances in the pure sciences, space travel, medicine, and computer science (among other things). Keep up on the news and share it with the children. Don't hesitate to have them report on things they have read, seen, or somehow heard about outside the classroom.

Of course, many teachers will have, as part of the classroom library, recent issues of National Geographic, National Wildlife, Ranger Rick's Nature Magazine, Audubon, and other popular periodicals for children and adults. These are highly recommended but should not, in any way, substitute for the suggestions in the previous paragraph.

7. INFUSE SCIENCE INTO OTHER SUBJECTS.

Few science textbooks promote the use of science content in other subject matter areas, e.g., math, language arts, and social studies. If a topic is being studied that truly excites the children, why not turn it to your advantage through composition, outside reading, panel discussions (or debates), etc.? Research has shown rather clearly that elementary students are particularly interested in animals, prehistoric life, certain aspects of earth science (volcanoes, earthquakes and the like), and reproduction (in the later years). These interests, carried over into math and language arts would most certainly pay rich dividends as content vehicles for skill development outside the science arena per se. (NOTE: An entire section of this methods book is devoted to the methods associated with the use of incidental science experiences and, therefore, will not be treated here).

8. PROMOTE STUDENT VIEWING OF SCIENTIFIC TV PROGRAMMING.

A surprising number of science-related programs have been and are being prepared for television. Although not limited to it, the PBS is a rich source of valuable viewing for children. Although not all such programs may be suitable for the elementary child, many are. A judicious selection of National Geographic Specials, NOVA Programs, Costeau Specials, the Life on Earth Series, the Cosmos Series, the Body Human, and others are rich in information for children. It should be remembered that many of these programs will bring the child into contact with illustrated content that would be next to impossible to communicate otherwise. A rich and diverse reservoir of educational viewing is there for the asking - free, motivating, usually well produced, colorful, entertaining, and often extremely valuable from a scientific literacy perspective.

9. SHARPLY DICHOTOMIZE BETWEEN SCIENCE AND TECHNOLOGY WHENEVER THE OPPORTUNITY ARISES.

Most textbooks (if not all) will treat both pure science content and technological content similarly, i.e., publishers present both as content without differentiating between the two. In the opinion of the writers, this is a fatal mistake. Students must understand the differences even though a close relationship exists between the two. Because this subject is dealt with elsewhere in this worktext, it will not be treated in more detail here.

10. USE CONCRETE EXAMPLES WHENEVER POSSIBLE.

Although the textbook has a major advantage over other science programs in that it can present information that cannot be learned via first-hand student experiences, it also has a potential that is often unrealized in the classroom. That potential lies in using concrete (real) examples of many of the concepts under development. Why read about frogs and not have one in the classroom? Why read about flying and not use model airplanes or the real thing at the local airport? Why read about soil types and not look at soil samples from the area? Why read about soil erosion and not put in a simple erosion control project on the school grounds or in the neighborhood? Why read about birds and not bring a live bird in from the petshop, or bring in a bird fancier or an accomplished bird watcher, or put up a bird feeder outside the window of the classroom? Yes, why not? There are few good excuses for not doing these things and a myriad of educationally sound reasons for doing them. You know enough about how children learn best to realize how true this last statement is!

Analyzing the Science Textbook Series

Training in and experience with textbook analysis is a practical enterprise for the science methods student. Most elementary teachers, at one time or another, must bear the responsibility for textbook selection. Similarly, you may well have a science textbook to work from on your first teaching assignment. It is expected that the analysis you will be conducting will further familiarize you with the textbook as a teaching device. This analysis will also help you examine some of the criteria the writers deem important in the selection process.

It behooves anyone considering textbook programs to compare products judiciously. To ignore the main objectives of science education in the local school's program is educationally unsound. Textbooks DO differ and accomplish different ends even when used with the greatest skill.

This assignment requires you to carefully analyze a particular science textbook program from several important standpoints. This analysis does not deal with many of the traditional criteria employed in textbook evaluation, e.g., reading levels. Instead, the criteria reflect, insofar as possible, scientific literacy itself, the advantages that can be gained by using a text, some of the disadvantages, and the ways in which the textbook can be modified in order to provide a sound science education experience of general education value for children. For the most part, the criteria employed are consistent with the goals of Project Synthesis - those goals so urgently required for the development of a scientifically-literate citizenry.

The assignment which follows asks you to choose a currently available textbook series and one grade level from that series in particular. Your selection will necessitate having access to the Teacher's Edition (due to certain tasks in the analysis). Be sure you give yourself plenty of time for the completion of this assignment. It is an extensive one and will necessitate some hard work on your part.

Textbook Appraisal

Your Name _____ Date _____

Publisher _____ Pub. Date _____

Author(s) _____ Grade Level Chosen _____

1. Certain science content is represented in particular chapters or units in every text, e.g., botany, geology, earth science. First, in the left hand column, list the unit/chapter titles presented in the textbook in the order in which they appear in the text and number them. Second, place the chapter number in front of each content area (right hand column) which is represented in that chapter. Several content areas might be associated with a particular chapter.

Chapter/Unit Titles	Content
_____	___ Chemistry
_____	___ Physics
_____	___ Earth Science, Astronomy
_____	___ Earth Science, Atmosphere/Weather
_____	___ Earth Science, Oceanography
_____	___ Earth Science, Geology
_____	___ General Botany (Plants)
_____	___ General Zoology (Animals)
_____	___ Anatomy or Physiology (NOT Health)
_____	___ Health
_____	___ Ecology
_____	___ Science-Related Societal Issues
_____	___ The Nature of Science/The Scientist
_____	___ Science/Technology Career Awareness
_____	___ Other _____
_____	___ Other _____
_____	___ Other _____

II. Are content areas covered that teach important conceptual knowledge that students cannot learn by first-hand experiences with objects and events in the environment, e.g., the solar system, space travel, oceanography, biogeography?

Yes___ No___. What is the evidence?

III. NOTE: Be sure you refer to the entire series in responding to this question.) Is the text a health/science fusion, i.e., does it cover mental and/or physical health as a basic part of science? And, in particular, does the text assist children in forming and maintaing good health habits? (Please do NOT consider the study of anatomy and physiology per se as evidence of health instruction.)

Yes___ No___. What is the evidence?

IV. Questions are asked of students in any science text. They are found interspersed within chapters or at a special section at the end of the chapter or both. Please study the manner in which the authors have stated these questions. Respond to the following:

A. To what extent do the authors ask the children to respond to questions measuring only low level factual information?

X	X	X	X	X
To A Minimal Extent		To A Moderate Extent		To A Great Extent

Why did you respond in this manner? (Evidence)

B. To what extent do the authors ask the children to respond to questions measuring the acquisition of concepts or the children's ability to apply concepts in new and unique situations?

X	X	X	X	X
To A Minimal Extent		To A Moderate Extent		To A Great Extent

Why did you respond in this manner? (Evidence)

V. Most texts claim that they are activity (experientially) oriented. These activities, oftentimes called experiments or investigations, are found interspersed within chapters or units or at a special section at the end of the chapter or both. Carefully examine the manner in which the authors have developed these activities. Then respond to the following:

A. To what extent are the activities structured to have the child inductively form a concept rather than deductively demonstrate an already pre-stated concept?

X	X	X	X	X
To A Minimal Extent		To A Moderate Extent		To A Great Extent

B. To what extent are activities developed so that there is an opportunity for open-ended, independent investigation rather than following a prescribed sequence of events which lead to a predetermined answer?

X	X	X	X	X
To A Minimal Extent		To A Moderate Extent		To A Great Extent

C. Briefly defend the responses you made to A and B above, i.e., why did you answer as you did? (Evidence)

VI. Is there any evidence in the student text to indicate that students gain a concept of what science is? This could be accomplished with a direct definition, discussion or repeated reference to science. Although a child might gain this concept inductively, by experiencing science in a realistic manner, your instructor must perceive an adequate explanation if you use this perspective in your reasoning.

Yes___ No___. Why did you respond in this manner?

VII. To what extent do the text's authors present information dealing directly with science-related societal issues? Examples of such issues would be genetic engineering, human population growth, endangered species, deforestation of tropical rain forests, etc.

X	X	X	X	X
To A Minimal Extent		To A Moderate Extent		To A Great Extent

Why did you respond in this manner? (Evidence)

VIII. To what extent do students get training in order to develop specific science processes, e.g., hypothesizing, comparing, classifying, predicting, and experimenting?

X	X	X	X	X
To A Minimal Extent		To A Moderate Extent		To A Great Extent

Why did you respond in this manner? (Evidence)

IX. To what extent are children evaluated in a manner that is consistent with stated objectives and/or textual content?

X	X	X	X	X
To A Minimal Extent		To A Moderate Extent		To A Great Extent

Why did you respond in this manner? (Evidence)

X. Most textbook publishers make a point of noting that a particular text develops important concepts. Choose any one specific concept from anywhere in the text, state the concept below, and continue with this part of the assignment as directed below: (An Example Concept: Energy is exchanged in the environment through food chains beginning with the food producing green plant.)

Write the chosen concept in this space:

Page ____:

A. What printed information and/or illustrations are found in the text which would help the child develop this particular concept?

B. What science experiences (laboratory or otherwise) do students get with regard to this particular concept? In other words, what do students DO to help them learn this concept?

C. What suggestions are there in the Teacher's Edition for the development of this concept?

D. Do A, B, and C above provide enough information and experiences to permit the thorough development of this concept? Defend your answer! Think it through carefully!

Yes___ No___. Why did you respond in this manner?

XI. Are various kinds of illustrations used to good advantage in this series? Consider how line drawings, full color art work, and full color photographs are used to supplement the learning of specific types of content/concepts. Comment using specific examples.

Yes___ No___. Comments:

XII. Please inspect the Teacher's Guide for the text you are analyzing. Respond to the following:

Does the Teacher's Guide . . .

A. . . .clearly present instructional objectives for each unit/chapter? Yes___ No___.

B. . . .provide the teacher with adequate supplementary information on the science content being presented to the students in each unit/chapter? Yes___ No___.

C. . . .provide the teacher with lists of resources he/she may go to for further information on the science content being presented in each unit/chapter? Yes___ No___.

D. . . .communicate teaching methodologies which would maximize teacher effectiveness in teaching the units/chapters? Yes___ No___.

E. . . .provide the teacher with descriptions of supplementary materials (e.g., films, filmstrips, trade books) which could be profitably used with students? Yes___ No___.

F. . . .provide suggestions to the teacher for integrating science content with other content areas in the curriculum (e.g., reading, social studies, composition, mathematics)? Yes___ No___.

G. . . .reflect an organization which would facilitate the teaching of the unit/chapter (i.e., make the teacher's task easier and/or more efficient)? Yes___ No___.

XIII. Please assume that, for one reason or another, you had to use this textbook series in your own classroom as the basic science program. With this thought in mind, please do the following:

A. List what you perceive as this text's general education (scientific literacy) strengths, if any.

B. List what you perceive as this text's general education (scientific literacy) weaknesses, if any?

C. Prepare a detailed explanation of how you would use this series, modify it, or supplement it in order to gain the best possible science program for your students? In other words, how would you use this series to provide for scientific literacy on the parts of your students? Please be very specific in your presentation. You may add a sheet to this assignment for your response if necessary.

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Since the beginning of knowledge must be with the senses, the beginning of teaching should be made with actual things. The object must be a real, useful thing, capable of making an impression upon the senses. To this end it must be brought into communication . . . if visible, with the eyes; if audible, with the ears; if tangible, with the touch; if odorous, with the nose; if sapid, with the taste. First the presentation of the thing itself and the real intuition of it, then the real explanation for further elucidation of it.

Johann Amos Comenius - 1657

PART IX

Preparing Instructional Materials

Performance Objectives

Subsequent to your interaction with this chapter, you will be expected to be able to. . .

1. . . . diagram the General Teaching Model (GTM) and discuss the relationships which exists between all the component parts. Further, describe the relationship that exists between the GTM and curricular goals.

2. . . . describe how the GTM can be used to facilitate instructional validity and efficiency. Further, you will be able to accurately explain what the authors of your worktext mean when they state that the GTM brings integrity to the teaching process.

3. . . . describe how the GTM permits the teacher, in the final analysis, to make his/her own instructional decisions.

4. . . . list at least three questions that teachers need to ask themselves when selecting performance (instructional) objectives for use with learners.

5. . . . list the three elements that must be contained in a well-written performance objective.

6. . . . construct performance objectives for particular content that meet the criteria demanded by well-written performance objectives.

7. . . . analyze performance objectives to determine: (1) whether they meet the criteria for well-written objectives and, (2) whether they measure what they purport to measure.

8. . . . provide a rationale for using pre-assessment during instruction. Also, provide a rationale for <u>not</u> using pre-assessment in certain situations.

9. . . . discuss and defend the two major reasons for conducting some form of evaluation as a part of the instructional process.

10. . . . state at least three reasons why students may be unsuccessful when evaluated.

11. . . . list several ways in which a teacher can make adjustments in his/her teaching strategy if students do not achieve the objectives at the desired level.

12. . . . apply the GTM model in the development of a science unit/module for use in the grade level of your choice.

13. . . . analyze the unit/module developed (see Objective No. 12) to determine: (A) how the parts of that unit reflect the components of the GTM, (B) to what

degree the components are consistent with each other, and (C) which Project Synthesis Goal Cluster(s) is/are represented by the unit/module's content.

Preparing Instructional Materials

Although this worktext is not a book for teachers dealing with curricula per se, there exists a substantial relationship between curriculum and the teaching methods associated with curricula. Different curricular programs demand different teaching strategies, i.e., methodological approaches. A "read about science program", for example, demands a far different instructional approach than a highly inductive program. If a science program is handed to you by your building principal or the curriculum coordinator, you are usually faced with the task of using instructional methods which are compatible with that particular program. Although this worktext focuses primarily on teaching methods, it must, by necessity, explore the curricular approaches which are available to teachers in order to facilitate an understanding of the methods demanded in different situations.

In this chapter, however, we are shifting the focus to the development of instructional units, modules, packages, or whatever term you wish to use in describing a self-contained instructional "entity" for use in teaching something of importance to children (any age level). There may be many times when, for any one of a variety of reasons, you are left "holding the bag" when it comes to preparing instructional (curricular) units for use with children. How do you make decisions about what to teach, how to choose your objectives, how to prepare for instruction, how to deliver that instruction, and how to evaluate the effectiveness of that instruction? Hopefully, this section of the worktext will help you in answering at least some of these terribly important questions.

In any instructional decision making process it is crucial to know precisely what your educational goals are. Earlier in this worktext we spent a goodly amount of your time focusing on scientific literacy as the overriding goal of science education and on a set of goal clusters felt to reflect a sound science program for literacy. You will recall that these goal clusters were: (1) personal needs, (2) societal issues, (3) academic preparation, and (4) career awareness. Elsewhere in the worktext we emphasized the fact that most science textbook programs and many modern, experiential programs as well do not teach to the bulk of these goal clusters. This means that, in most school settings, you will have to plan for and deliver instruction that goes beyond readily available, commercially prepared materials.

In order to plan for and deliver sound instruction for children, you need access to an instructional model that can be used in the development of instructional units. Needless to say, this model should be one that helps guarantee the validity of the material being produced. Such a model does exist and it is strongly recommended that you become skilled in its use - a task that is a substantially difficult one for most beginning and experienced teachers. This model is called the General Teaching Model - the GTM.

The General Teaching Model (GTM)

The General Teaching Model (GTM) was developed at Southern Illinois University at Carbondale in the 1970's by Roger E. Robinson and David T. Miles. It was revised in a document published by the SIU-C School of Medicine in 1979. The GTM has received national and even international recognition as one of the best devices available for improving instruction at all grade levels of education, in all subject matters, for any length of instruction from a few minutes to a semester.

The GTM is seen as having two major functions. These are: (1) guiding teachers through the major steps of designing and carrying out instruction and (2) providing a structure (model) with which to view and examine the teaching process. The original developers point out that good teachers will find considerable similarity between the GTM and the procedures they employ in teaching. Viewed thusly, the GTM can be described as an attempt to make explicit what makes an effective teacher effective.

The authors of your worktext would like to take the above comments one step further. The GTM, if used properly, brings integrity to the teaching process. Far too often we observe teachers (elementary, secondary, college professors) who advocate a particular set of objectives, teach for what is apparently another set of objectives and then evaluate students on a mysterious third set of objectives. Not only is this poor teaching as such, it is totally unethical in that students do not know what it is they are expected to learn and, therefore, do not achieve at a level that is commensurate with their potential. This waste of human talent and intelligence could, in large part, be avoided if teachers would only analyze their own instructional process and learn to apply the GTM rigorously and consistently.

Teachers sometimes complain that the GTM takes away from their creativity and academic flexibility. To some extent this may be true. However, the GTM does not act as a guide for what will be taught, does not dictate instructional methods, and does not dictate evaluation strategies. Even using the GTM, the teacher must decide what is to be taught, how it will be taught, and how the entire process will be evaluated. These decisions rest with the teacher - the GTM only guarantees the integrity of the instruction and then only if used properly.

Now, let's take a look at the GTM section by section. This may produce a better understanding of it and help begin the development of those skills needed for implementing this model.

Instructional Objectives (A)

Instructional objectives are critical to the entire process of curriculum development and instruction. They establish what the learner is to learn, i.e., what the teacher is to teach.

Of course, the selection of instructional objectives is a matter of considerable importance. Although this topic is not dealt with in depth in this chapter, it is important to remember that one cannot go about the business of selecting objectives in an intuitive manner. There must be some serious educational premise for the selection of objectives. Among the most important considerations are:

1. Are the objectives being considered consistent with the goals of this course, e.g., Project Synthesis Goal Clusters?

2. What should the students be able to do subsequent to the unit/module?

3. What prerequisites are demanded by the content being taught in this unit/module?

4. What instructional resources are available to the instructor of this unit/module?

5. What must this course provide students in order for them to be successful in subsequent grade levels?

Generally speaking, objectives can be classified into one of three types (domains of behavior). These three domains are:

1. The affective domain: This domain deals with emotions or feelings. Here we run into descriptions associated with things like values, attitudes, interests, motivation and appreciations.

2. The cognitive domain: The cognitive domain must be broken down into two subcomponents. These are:

   A. Cognitive knowledge: Cognitive knowledge deals with what an individual knows, e.g., a particular body of knowledge, conceptual structure.

   B. Cognitive skills: Cognitive skills are those intellectual attributes that permit a learner to enter into problem solving, information processing, evaluation and the like. Cognitive skills are represented by such things as inferring, classifying, hypothesizing, interpreting data.

3. The psychomotor domain: This domain deals with attributes associated with physical movement, i.e., some mode of physically acting on the environment. There are a number of levels of accomplishment associated with the psychomotor domain, e.g., imitation, naturalization.

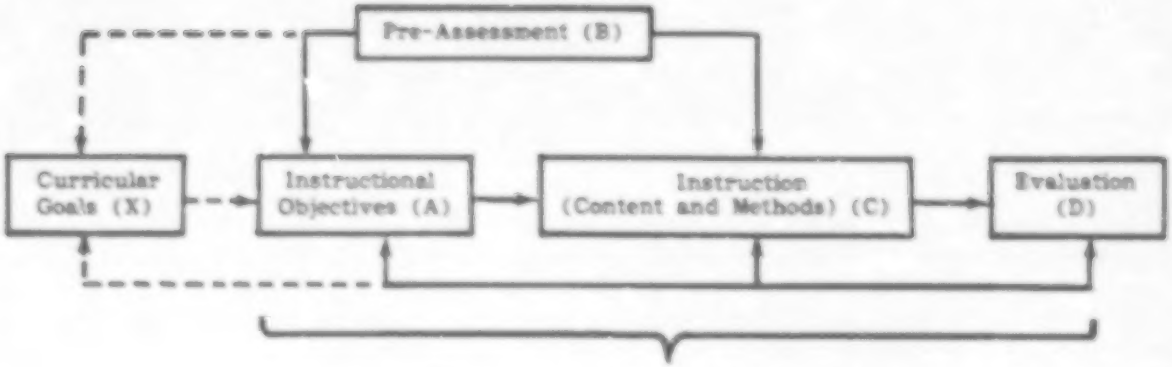
Often, objectives do not fit exclusively in one of these domains. One can often observe some element of two or more domains in an objective. Still, it is usually possible to determine which domain is predominately displayed in an objective. This permits the instructional designer to determine whether there is an adequate number of objectives which fit the domains needed in the development of particular learner behaviors.

Many who promote the use of performance (behavioral) objectives would say that an objective should reflect three main elements. These are:

1. A description of the testing strategy.

2. The specific mode of performance deemed important.

THE MODIFIED GENERAL TEACHING MODEL (GTM) AND ITS RELATIONSHIP TO CURRICULAR GOALS



The Modified General Teaching Model (GTM)

This figure diagrams the modified GTM (A, B, C, & D) plus its relationship to curricular goals (X), e.g., Project Synthesis Goal Clusters/Subgoals. A, C, & D are the critical components of this model which must be considered in all cases. Pre-Assessment (B) must also be considered as an integral component when needed in the instructional process. Note the interrelatedness of all components. These relationships must constantly be respected in any instructional development process in order to maintain any semblance of instructional validity/integrity.

3. The level of performance necessary before the behavior is deemed acceptable.

The authors, on the other hand, are willing to express these elements in far simpler terms. Namely, you should be able to remember these elements as:

1. The <u>what</u> of the objective.

2. The <u>how</u> of the objective.

3. The <u>how much</u> of the objective.

In other words, <u>what</u> the student is supposed to do, <u>how</u> he/she is to do it, and <u>how much</u> of that behavior is expected.

Let's see how this might work. Assume for a moment that you are teaching sixth grade science and one of the units deals with geologic processes. One of the major ideas (a concept) in the unit might be as follows:

> Rocks on the surface of the earth are attacked and decomposed by the agents of weathering.

You prepare a set of objectives for this unit and the one dealing with this concept looks like the following:

> Objective: Upon completing the unit, the student will be able to define weathering in one written sentence and list three agents of weathering.

Does this objective tell what the student should do? Does this objective tell how the student should meet the objective? Does this objective state how much of the behavior is expected? The answer to all these questions is "yes". Now, the question is: Is this a good objective? It certainly meets the three criteria established for writing objectives, doesn't it? But, the question remains: Is this a good objective?

The test for whether or not an objective is "good" goes well beyond whether it meets the criteria for writing an objective. One must also determine whether the objective tests what it is supposed to test, i.e., does it measure what is intended? In the case of the weathering objective, the student is asked for a definition and an identification of three forms (kinds) of weathering. If the teacher wants to know if the student understands the processes involved in weathering, the objective falls far short of accomplishing this. Further, if this content is important, the teacher should probably want to determine whether the concept of weathering has actually been learned. Therefore, the original objective is inadequate and needs to be rewritten. How would you go about revising it?

First, you would need to determine how you could measure whether the student understands the concept of weathering. Second, you would have to construct an objective or series of objectives which would permit you to observe some level of comprehension on the parts of the students. Your new objective(s) might look like the following:

> Subsequent to the unit on geologic processes, the student will be able to . . .
>
> 1. . . . list, in writing, three important agents of weathering.
>
> 2. . . . explain, in written paragraphs of no more than 40 words each, how each of these weathering agents attacks rocks at the surface of the earth.
>
> 3. . . . explain, in a paragraph of no more than 30 words, why weathering takes place only where rocks are exposed at or near the surface of the earth's crust.

Are these objectives more adequate for the task at hand? Probably! Although there might be differences of opinion concerning how this concept acquisition should be measured, there is no question that the three objectives written above would better tell the teacher whether the students had actually conceptualized the ideas related to weathering.

Thus, the writing of performance objectives is no easy task. It can be a frustrating and difficult experience. Even so, the use of performance objectives which are well thought out and well written can bring a great deal of integrity to

the teaching process. They do, in fact, determine what the teacher is to teach and what the learner is to learn . . . all in all, a pretty good prescription for effective instruction.

Science methods students needing experience with the evaluation of, analysis of, or writing of performance objectives should use Appendix C in this work-worktext.

Pre-Assessment (B)

Two sound reasons exist for using pre-assessment. These are:

1. To determine whether students have the prerequisites necessary for what the teacher anticipates teaching. This would determine whether the teacher needs to revise the instructional plans he/she has ready for delivery. Or, it could ascertain if there were individual students who needed remediation before entering into the content under construction. If this was the case, remedial activities could be designed for those students needing same.

2. To determine how much of the content in the forthcoming unit students already know. Can the teacher omit any of the objectives for this unit for either the entire class or individual students? If this is the case, instructional time could be shortened and/or made more efficient.

In the original GTM, Robinson and Miles place Pre-Assessment in line with all other components, i.e., they did not bring it out of a linear pattern as the authors of your worktext have done. Why did the authors alter the position of Pre-Assessment in the GTM? They certainly do not disagree with the use of pre-assessment in an instructional setting. However, they do feel that as important as Pre-Assessment is, it need not be used in every situation when a new unit/module is being introduced. This is particularly true when instructional units are sequential in nature or where the instructor knows the students well. Therefore, in the diagram shown on page 185 Pre-Assessment is shown above the other three components.

How does one go about deciding how to pre-assess? Although this depends considerably on the content being covered and the teacher's familiarity with the students, a number of strategies could be employed.

One strategy for pre-assessing is simply to choose test items from those which would be used in the evaluation phase of instruction and use these. If there is a wide range of test items, one would have to be very careful to choose those which would represent the terminal behaviors being worked toward. If there is a large selection of test items representing a limited amount of content then a random selection of items might suffice.

Another strategy is to construct test items which parallel evaluation items and use these in pre-assessment. This avoids some problems associated with using the same items twice.

In situations where the instructional unit/module is short-term in nature, less extensive pre-assessment may be required. At times the teacher may simply

want to hold a brief discussion concerning the content with the class in order to determine the general level of student preparation for the content. Individual interviews with students have also been suggested as a means of pre-assessment. This strategy would be particularly useful in classrooms where instruction was individualized.

Instructional Procedures (C)

What kind of instruction should be used after the objectives have been written and pre-assessment completed? Of course, there is no simple answer to this question. Choosing the proper instructional strategy depends on which will be the most effective and most efficient for getting students to achieve the instructional objectives. This is controlled by a number of factors including the teacher's repertoire of skills, the instructional materials available, the kinds and ages of the learners, and the setting(s) available for carrying on the instruction (e.g., laboratory, regular classroom, outdoor facility).

A wide variety of instructional strategies are available from which to choose the one (or more) which would be appropriate. Among these are: lecture and/or discussion, directed inquiry, open-ended inquiry, tutoring, teacher demonstration, independent study, programmed instruction, and reading. It is evident that all of these are not appropriate for a particular instructional need. Thus, careful planning is once again extremely important.

Once the overall instructional strategy is chosen, it is the teacher's responsibility to meet certain criteria for maximizing learning. In most situations a number of instructional principles should be utilized as a part of the instructional process. Research into learning indicates that many principles have proven to be helpful to the learning process. Among these are:

1. Pre-learning preparation: . . . the use of advance organizers in order to direct the learner's mind toward that which he/she should be learning.

2. Motivation: . . . promoting a desire to achieve the objectives.

3. Providing models of terminal performance: whenever possible, students should be shown examples of what they are to produce/do subsequent to instruction.

4. Active responding: . . . students need to do what they are expected to learn to do, i.e., it is what learners do that determines the learning that takes place.

5. Practice: . . . if a new behavior is important, the learner needs to use it repeatedly in order to retain it over the long term.

6. Knowledge of results: . . . learners need to have prompt and frequent input concerning their level of success and be put back on track whenever they falter in their search for mastery of the objectives.

7. Graduated sequence of subject matter: . . . what is to be learned should be organized in a hierarchical manner from simple to complex or from familiar to the unfamiliar.

8. Providing for individual differences: . . . teaching content in a manner that permits learners to proceed at their own pace given that human beings learn at different rates.

9. Social and personality factors: . . . research indicates that a teacher's personality and social skills make a tremendous difference in instructional effectiveness.

Evaluation (D) Evaluation is typically conducted at the end of a unit/module. Evaluation usually involves the use of some type of test to measure the acquisition of knowledge, skills, or attitudes. Certain objectives can, of course, be measured during the course of instruction, e.g., via observations of participation in labs, products produced for particular assignments, oral recitation. The instructor must determine when learners should be evaluated and how evaluation should take place.

Several ideas associated with evaluation appear crucial to the topic. These are:

1. Evaluation should be consistent with the objectives for the unit. Does this mean that the teacher must evaluate every objective? Not necessarily. It does mean, however, that the teacher must not enter into an "apples-oranges" phenomenon, i.e., stating an objective in a particular way and then evaluating in a completely different manner (one unexpected by the students). An example might prove helpful.

Suppose you had written an objective demanding the ability to compare and contrast characteristics of amphibians and reptiles. Then you write one multiple choice question asking for the identification of reptile characteristics and another for amphibian characteristics. Would this suffice? Absolutely not! In this instance you are asking the student to recall knowledge of the characteristics of the two groups of organisms - not to compare them one against the other. The original objective is one that is skill based whereas the test questions are knowledge based.

2. Evaluation should be used to measure the effectiveness of instruction. This idea is truly an important one and also one that is often ignored by teachers. How well students perform on an evaluative instrument indicates how effective instruction has been. Therefore, teachers should always look carefully at the results of evaluation to analyze as precisely as possible the effects of instruction.

If evaluation results indicated unsuccessful instruction, it is probably the result of one of the following:

A. Students lacked the prerequisites necessary for the successful completion of the unit/module.

B. Instructional activities were not designed adequately.

C. Instructional activities were not implemented adequately.

D. The evaluation measure was invalid, i.e., it was not measuring what it was supposed to measure.

In the final analysis, evaluation either during or subsequent to instruction (or both) should indicate to the teacher how successful instruction has been. If unsuccessful, objectives need to be revised, or instruction needs to be changed, or evaluation needs revision, or all of the above. It is truly important to design instruction so that as many students as possible achieve as many objectives as possible while, at the same time, retaining a positive attitude toward learning.

A Mini-Model Illustrating the Application of the GTM

The writers of your worktext are of the opinion that you might appreciate an example of how the GTM would look in actual practice. One example exists in the layout of this worktext. Consider the presence of performance objectives in this worktext, the material presented in each chapter, what takes place in class, and how you are evaluated. This is one example of an effort to design an entire course based on the GTM.

Another mini-example is presented below. We are setting up an abbreviated portion of a unit on adaptation. Let's see how this might lay out.

THE GOAL: Students will learn that organisms are adapted for survival in the environment in which they live.

UNIT (ABBREVIATED): ADAPTATION

PERFORMANCE OBJECTIVES:

1. . . . orally describe how some prey organisms are adapted for survival through protective coloration.

2. . . . identify or write at least six examples of organisms that are able to survive because of protective coloration.

PREASSESSMENT:

Name two prey organisms that are helped to survive because they are a particular color in their environment. Explain <u>how</u> these colors increase survival chances for these organisms.

INSTRUCTION:

- Definition and discussion of protective coloration in prey organisms.

- Examples and discussion of prey organisms protected through protective coloration plus examples drawn from learners.

- Bulletin board w/colored photographs of examples of protective coloration.

- Outdoor laboratory using a variety of dyed - colored - toothpicks (green, red, yellow, blue, and natural wood color), twenty of each color, scattered onto a grassy area 5 meters by 5 meters. Three "predator" learners from the class are given one minute to retrieve as many of each color as they can. Data recorded and analyzed back in the classroom. Discussion following, concluding that some colors in a grassy plot would be more effective than others for escaping predators.

- Summary discussion to determine whether learners seem to have the concept as well as a substantial number of examples.

EVALUATION:

1. In a written paragraph of 40 words or less, describe how protective coloration helps certain prey organisms survive in their environment.

2. List six separate prey organisms which are helped to survive because they have developed protective coloration.

END

In the mini-example displayed above, is there consistency between the elements, i.e., between the goal, objectives, pre-assessment, instruction, and evaluation? Will the evaluation measure what the instructor intends to measure? Should there have been one or more additional objectives?

The mini-example demonstrates how the components of the GTM fit together and how the GTM relates to educational goals. A substantial amount of consistency exists between the elements. The question concerning whether there should have been one or more additional objectives can only be answered in terms of the extent to which the teacher chose to develop the concept and the age and background of the learners. The writers of your worktext would have probably added an objective dealing with the effect of protective coloration on the survival of a species as a whole. This would have necessitated additional instruction and a more thorough understanding of the concept of the variables associated with the continuation of survival for a species rather than for individual organisms. This decision, however, is one predicated on the background of the teacher and the maturity of the learners.

PART X

The Incidental Science Experience (I.S.E.)

Performance Objectives

Subsequent to your interactions with Part X you will be expected to be able to. . .

1. . . . define an incidental science experience (I.S.E.) or choose the appropriate definition from a list of alternatives.

2. . . . identify or describe at least two ways the I.S.E. can be used as a vehicle to develop language arts skills.

3. . . . identify at least two reasons why the I.S.E. is a valuable strategy to use with culturally disadvantaged children.

4. . . . cite two examples of situations (other than those described in the reading) that could be defended as an I.S.E. and specify how each could be developed into a science learning experience to develop conceptual knowledge.

5. . . . defend the use of a contrived I.S.E. in the classroom and give one example of such a situation stating its application to science education and/or other content areas.

6. . . . defend the position that the use of incidental science experiences does not substitute for a science program that has substance, scope and sequence.

7. . . . demonstrate the ability to teach an incidental science experience and produce a language experience chart subsequent to that experience.

The Incidental Science Experience (I.S.E.)

The word incidental is defined as being an undesigned feature of something; casual; of secondary importance; accessory. Therefore, an incidental science experience (I.S.E.) might be defined as a casual or undesigned happening related to science instruction in the classroom. Of particular importance is that it need not be of secondary importance. Indeed, for certain purposes the incidental science experience can be extremely important.

What might constitute an I.S.E.? A wide variety of possibilities exist. A child may bring a sack of sea shells to class after a visit to the Gulf coast. A

* A substantial portion of this chapter appears here by permission of Instructor; see H. R. Hungerford, "Science Every Day - The Incidental Approach," Instructor, 81, 9 (May 1972), 46.

meteor might flash across the night sky and receive wide publicity. An animal might have babies during class time (this has happened more than once). An experiment or demonstration might take a very unplanned turn of events. This could certainly be considered of an incidental (and perhaps unwanted) nature. The teacher might even plan certain "incidental science experiences" for certain students or groups of students.

One very pertinent factor regarding incidental experiences is that they provide high motivation as children seem to be intensely interested in many things that seem discrepant to the normal routine of the classroom. To fail to take advantage of such high interest moments seems unrealistic. They are often the most "teachable" moments.

Few science educators would propose that the I.S.E. be allowed to substitute for a science program that has substance, scope and sequence. And yet, for certain groups such as culturally deprived children, the incidental experiences, at the primary level particularly, may be of as much value as a more sophisticated science program if used persistently and intelligently. Regardless of the teacher's philosophy, it appears pertinent to explore the values of the I.S.E. so that greater use can be made of it in the classroom.

What will the I.S.E. do for the education process? First, as noted before, they provide an opportunity almost without equal for broadening the experiential backgrounds of children. Many students with very limited experiences with their environment should profit tremendously from this strategy. There should be impact for other content areas as well, e.g., reading, language arts.

Second, the I.S.E. will provide content of high interest for use in language arts. The use of experience charts in conjunction with incidental science experiences has been used often with outstanding results. Similarly, writing skills can be practiced with little concern for having to motivate children to tackle the assignment. Many experiences find children searching for more information - going to the library to "look things up" or finding someone who has more information to ask for help. Possibilities are numerous.

Third, some kinds of incidental experiences find students involved in actual science research that would never have taken place without the opportunity provided by the I.S.E.

An example of this kind of research might help. Some years ago the writer had a student teacher at the middle school level who had occasion to set up what is some times referred to as the "Pasteur Spontaneous Generation Experiment". The demonstration is a relatively simple one consisting of five flasks, each containing a nutrient broth in which microorganisms can flourish. In turn, each of these flasks is exposed to the air in a different way using one-hole rubber stoppers and glass tubing. Three of the flasks are set up so that spores in the air can get into the broth and begin growing. Two of the flasks are stoppered so that spores cannot get into the broth. If spores get into the flasks the change in the broth is dramatic within a few days. There can be no question about whether something is going on inside. Both eyes and nose collect information to verify this.

The student teacher set up the demonstration, gave specific instructions to students to carefully observe all flasks, and was horrified to find that growth was taking place in flasks where no one expected mold or bacteria to be found.

He came to the writer in near panic to implore him to suggest some way to salvage his demonstration and his pride. It was suggested, since every student was aware of what had happened, that he squarely face the problem with the students and admit something had gone wrong. Also, it was suggested that he explain how the demonstration has been set up so that the students could conceptualize the process. Then, he might ask the students to hypothesize reasons for the failure of the demonstration and to come up with an alternative method of setting it up so it could be tried again, this time with student help. Pride wounded, the student teacher did all of these things. To his great surprise, the students respected his honesty, seriously approached the hypothesizing, and enthusiastically entered into the work involved with setting up a duplicate experiment. The next time there was no failure and when the student teacher left the writer's jurisdiction he unhesitatingly admitted that this had been his most profitable lesson as a student teacher - for him and for the students. Indeed, it was, and it was the direct result of an I.S.E.

One of the concerns of many elementary teachers is their own knowledge about science. There are those teachers that adamantly refuse to cope with an I.S.E. because they feel so inadequate in the affairs of science, particularly unexpected situations like those in question. This is hard to understand because the knowledge in science is so substantial that no one has all the answers. Students who are naturally curious about an object or event are also usually quite willing to research it and report to all concerned (including the teacher). To fail to grasp a classroom situation ripe with positive educational potential seems somehow unethical and, at best, in poor judgment.

How long should a teacher persist with the use of an I.S.E. for purposes of instruction? Certainly, it seems unwise to use it for a period longer than motivation exists. Let the children satisfy their curiosity and then move on. If other than this is done the students may find their curiosity suddenly repressed if they anticipate only hard work and drudgery as a result of expressed interest.

Earlier the point was made that incidental science experiences have value for the language arts. Reference was made to experience charts. Let us take a look at a couple of examples that actually originated in University School at Southern Illinois University. The first is the result of a walk taken by first graders on a warm day in autumn. Many things were observed and upon returning to the classroom some of these were recorded by the students via the experience chart method. The prose elicited from the children follows:

OUR FALL FIELD TRIP

We went on a fall field trip.
We were looking for signs of fall.
The leaves have changed colors.
We saw red, yellow and yellow-green leaves.
Some of the trees were bare.
Patty found some tiny leaves of different colors.
We found some milkweed.
Milkweed seeds fly in the fall.

In that same first grade classroom, the students "discovered" fossils one day at recess in the rocks that formed a wall on one side of the school building. They literally buzzed with excitement. The teacher saw a golden opportunity to capitalize on this event and make it into a very productive science experience. She sought out the writer and borrowed several dozen fossils. The children inspected these and made pencil rubbings of those that were fairly flat. She then asked a geologist to come in and talk about fossils with the children. Lastly, she found a sound filmstrip on fossils and showed it to the youngsters. Subsequent to this set of experiences, she wrote a language experience chart as the children dictated it to her. She confided to the writer later that the children wanted to use the word "paleontologist" in the story but that she didn't do it because she couldn't spell it. Remember, these were first graders. When asked whether the children would have been able to read an experience chart with that kind of vocabulary, she unhesitatingly responded, "Of course!" When produced by the children in this format, the prose can be read by the children. Somehow that seems like a very useful principle to remember. The "Fossils" experience chart follows:

FOSSILS

We found some fossils in the rocks on the playground. Fossils are very old. It takes thousands of years for fossils to be made.

There are many kinds of fossils. Some are plants and some are animals. They are the marks left in rocks after the plants and animals died. Fossils are formed in many ways. Scientists study fossils to learn about the plants and animals that lived long ago.

Another example of the use of experience charts is from kindergarten. Two very bright boys were intrigued by an ant farm provided by the teacher. Each day they observed the ants and gave their observations to the teacher who recorded them on an experience chart. The boys were so interested in the activity that a copy of the chart was made for each day and the boys took them home. A section of one experience chart contained the following:

TUESDAY, OCT. 14

Today there is another tunnel along the top.
We found another dead ant today.
The ants are picking up dirt and putting it on top.
We fed the ants.

WEDNESDAY, OCT. 15

The tunnel along the left hand edge is
longer today.
It looks like a new tunnel is beginning
in the middle.

The boys were sharpening their skills of observations and comparison, recording data in a systematic fashion and learning to communicate in a clear and informative manner. Such are some of the benefits that can be derived from an incidental science experience.

If children are hesitant to volunteer their own incidental science experiences, the teacher should encourage them to do so and to share their enthusiasm and findings with fellow students in the classroom. It can be handled much like the "show and tell" technique so often used by primary teachers. If this strategy fails, the teacher should not hesitate to "stack the deck" and provide highly motivational events until the students begin responding with their own. A gerbil or pair of gerbils can be extremely motivational in any classroom, K-8. What child fails to be interested in a box turtle? The thrill of using a high-powered microscope (borrowed from the local high school biology teacher) to peer at tiny organisms is apparent at almost any age. Why not invite a jet pilot to drop by for a classroom visit?

In Summary Incidental science experiences are ones that are of immediate concern and have usually been unplanned. Many incidental experiences can be anticipated in the elementary school. They are highly motivational. Incidental experiences can provide a rich source for broadening experiential backgrounds in science. Similarly, they have great potential as vehicles in language arts instruction. Teachers should not be reticent about using an I.S.E. because he/she is fearful of his/her own inadequacies.

PART XI

Understanding and Teaching Environmental Education (EE)

Performance Objectives

Subsequent to your interactions with this part of your worktext, you will be expected to be able to. . .

1. . . . pose a definition for environmental education (EE) which is consistent with the one presented in the worktext.

2. . . . explain why EE involves issues, values, and resources.

3. . . . communicate a rationale for EE being urgently important in elementary and junior high schools. At least part of this rationale should encompass summary findings of Global 2000.

4. . . . define "environmental literacy" stating or identifying the superordinate component of literacy and the four subordinate literacy components.

5. . . . discuss, in depth, the literacy attributes (outcomes) found under each literacy component (I through IV) and the reasons why these literacy attributes (outcomes) are important for students.

6. . . . describe what is meant by the "infusion model" for EE and how EE might fit into existing elementary and junior high courses. Further, a rationale for using the "infusion model" should be communicated.

7. . . . identify the variables associated with environmental literacy as described in the worktext. These are: (1) knowledge of issues, (2) beliefs, (3) values, (4) attitudes, (5) locus of control, (6) sensitivity, (7) environmental action, and (8) ecological knowledge (concepts). Further, you should be able, to communicate why each of these variables is important for achieving literacy.

8. . . . discuss some of the benefits and conditions associated with values clarification in educational settings. Among these should be: (1) the educational benefits for students, (2) the role of knowledge and beliefs in value acquisition, (3) the role of teacher bias in values clarification, (4) the "value fair" classroom setting, (5) questioning strategies associated with values clarification, and (6) activities that might have potential in the elementary and junior high classroom.

9. . . . describe how an individual's belief and value systems can, at times, be in conflict with each other. Further, describe the educational implications of these conflicts.

10. . . . discuss the importance of having students investigate and evaluate environmental issues themselves. Also, be able to communicate important educational objectives associated with issue investigation, i.e., skills needed by students in order to successfully investigate issues.

11. . . . list and define the five environmental action categories.

12. . . . list the two major levels of environmental action and state which is usually most effective and why it is more effective.

13. . . . list at least ten of the thirteen questions that should be answered before an environmental action is decided upon. Included in the ten listed must be the one dealing with ecological implications. Further, the importance of answering each of these questions should be described.

14. . . . state why it is probably unethical to force elementary and junior high students to undertake environmental action as a required part of their educational program.

15. . . . describe the EE activities undertaken as a part of this methods course and state how these activities could be used (or modified for use) in elementary and/or junior high classrooms.

16. . . . if given the assignment, conduct an autonomous investigation of an environmental issue of your own choosing, lead a discussion of that issue in methods class, and communicate to your instructor how this investigation influenced your own beliefs, values, and environmental literacy overall.

> The earth as a life-support system is deteriorating. This the reader must understand clearly, in case he hasn't noticed or has been persuaded otherwise. In some respects our children's world will be better than ours, but on balance it will be uglier, less interesting, and more dangerous. This is not a pleasant fact to face, but denial is not a sufficient response to the problem.
>
> R. Thomas Tanner - 1974

Understanding and Teaching Environmental Education (EE)

What IS Environmental Education (EE)?

Environmental education (EE) is a confusing term in many educational quarters. In fact, it is sometimes easier to tell what it is not than what it is. The term EE has been used by outdoor educators, conservation educators, nature interpreters and many others as an umbrella under which to house their own activities. If this is true, how can we get a handle to the term?

The answer to this sticky situation lies, in large part, in a conference held in Tbilisi, Russia in 1977. This conference was sponsored by Unesco-UNEP (United Nations Environmental Program). Representatives from over 100 Unesco member nations attended this conference. The conference was designed to produce a document which would establish boundaries for EE and try to get the nations of the world involved in the teaching of EE (in the world's schools and communities in general).

The Tbilisi conference produced a set of five objectives for EE which focused on five areas of educational concern. These five objectives were: (1) environmental awareness, (2) environmental knowledge, (3) attitudes, (4) environmental skills, and (5) citizen participation in the resolution of environmental problems. These five objectives provided a very basis for defining environmental education in a meaningful way.

From the Tbilisi conference objectives, a definition emerges which tells us what EE is. It follows:

> Environmental Education: EE is that part of education that that deals with culturally-imposed, ecologically-related issues in the environment. . . . further, the acquisition and application of human values as they relate to the use and misuse of both living and nonliving resources.

The definition stated above means simply that EE is issue oriented, focusing on those issues which man has created and which have ecological implications. It also recognizes that issues are value related and that human values, in large part, dictate how the earth's resources are to be used.

So What?
Why Bother?

Rationales for EE in the schools are many - although we do not currently observe EE as a pervasive part of the elementary school curriculum. For example, a number of states have passed legislation making it mandatory to teach EE. A number of elementary science textbook writers have incorporated EE into textbook programs. Even some of the modern, experiential science programs flirt with EE in their scope and sequences, e.g., the Science Curriculum Improvement Study. Even so, these rationales are substantially poor ones because it is hard to legislate sound instruction and some schools don't even teach science, let alone the critical components of EE.

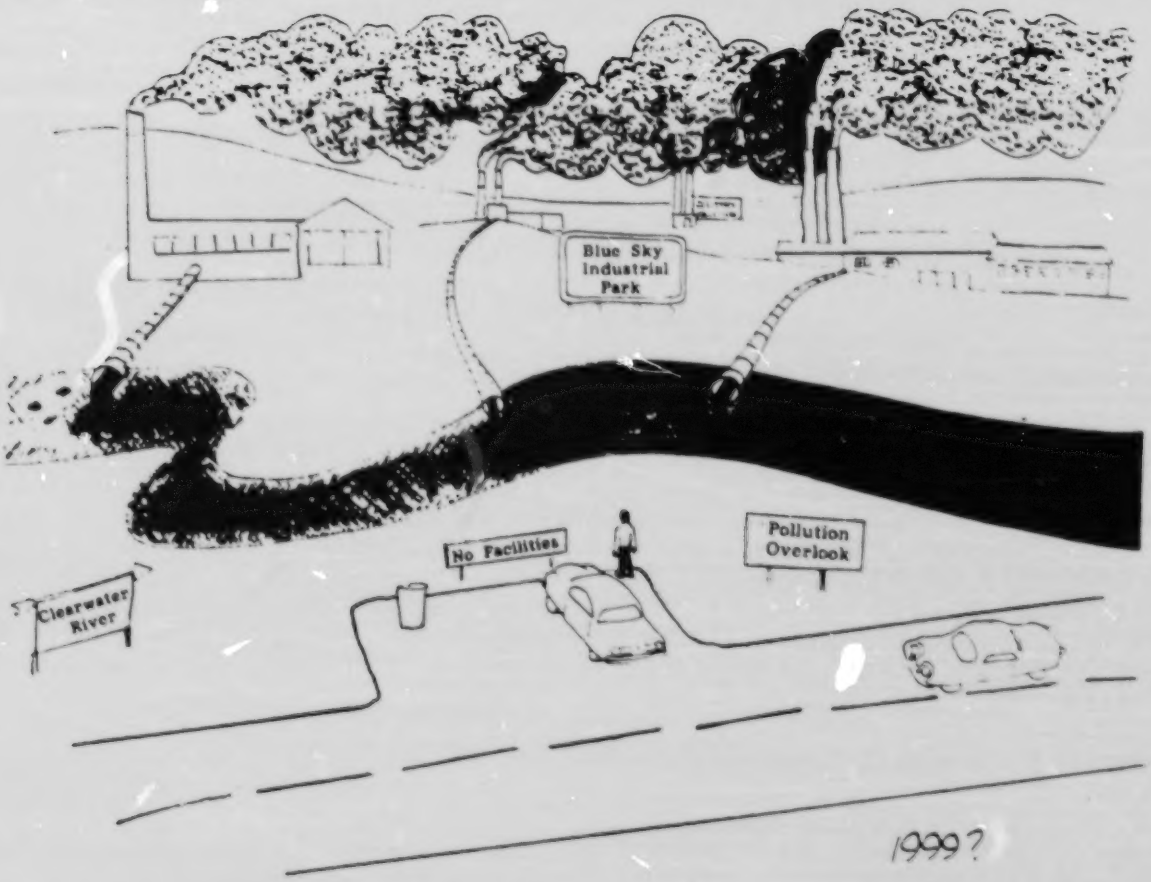
The writers would suggest that EE should be taught throughout the elementary and junior high school simply because it may be the single most important part of the curriculum. With a statement this bold and outspoken, there should be some evidence to support it. Is there?

Evidence for the crucial importance of EE exists in many documents or articles produced by many agencies and individuals. The writers could literally bury the reader with supporting data but choose, instead, to refer to the Global 2000 Report to the President of the U. S. "Global 2000" is documentation of a study ordered by President Carter in 1977 which was printed in 1979. The main purpose of this study was to seriously explore critical environmental issues on a

global basis and to predict the status of these issues in the year 2000. The responsibility for putting the report together went to the Department of State and the Council on Environmental Quality. The study's director was Gerald O. Barney, a recognized expert on population, resources, and environmental issues.

The Global 2000 Report to the President of the U.S. - Entering the 21st Century - Volume 1: The Summary Report was published by Pergamon Press (New York) in 1980. The authors of your methods text feel that a few paragraphs and statistics taken from this document support their contention that EE is a critical component in a youngster's education. These quotes follow (all taken from Part 1 - Major Findings and Considerations):

> If present trends continue, the world in 2000 will be more crowded, more polluted, less stable ecologically, and more vulnerable to disruption than the world we live in now. Serious stresses involving population, resources, and environment are clearly visible ahead. Despite greater material output, the world's people will be poorer in many ways than they are today.
>
> For hundreds of millions of the desperately poor, the outlook for food and other necessities of life will be no better. For many it will be worse. Barring revolutionary advances in technology, life for most people on earth will be more precarious in 2000 than it is now - unless the nations of the world act decisively to alter current trends. . .
>
> Rapid growth in world population will hardly have altered by 2000. The world's population will grow from 4 billion in 1974 to 6.35 billion in 2000, an increase of more than 50 percent. The rate of growth will slow only marginally. . .
>
> While the economies of the less developed countries (LDCs) are expected to grow at faster rates than those of the industrialized nations, the gross national product per capita in most LDCs remains low. The average gross national product per capita is projected to rise substantially in some LDCs (especially in Latin America), but in the great populous nations of South Asia it remains below $200 a year (in 1975 dollars). The large existing gap between the rich and poor nations widens.
>
> World food production is projected to increase 90 percent over the 30 years from 1970 to 2000. This translates into a global per capita increase of less than 15 percent over the same period. The bulk of that increase goes to countries that already have relatively high per capita food consumption. Meanwhile per capita consumption in South Asia, the Middle East, and the LDCs of Africa will scarcely improve or will actually decline below present inadequate levels. At the same time, real prices for food are expected to double.



Arable land will increase only 4 percent by 2000, so that most of the increased output of food will have to come from higher yields - fertilizer, pesticides, power for irrigation, and fuel for machinery - depend heavily on oil and gas.

During the 1990s world oil production will approach geological estimates of maximum production capacity, even with rapidly increasing petroleum prices. . . For one-quarter of humankind that depends primarily on wood for fuel, the outlook is bleak. Needs for fuel wood will exceed available supplies by about 25 percent before the turn of the century. . .

Regional water shortages will become more severe. In the 1970-2000 period population growth alone will cause requirements for water to double in nearly half of the world. . .

Significant losses of world forests will continue over the next next 20 years as the demand for forest products and fuel wood increases. . .

> Serious deterioration of agricultural soils will occur worldwide, due to erosion, loss of organic matter, desertification, salinization, alkalinization, and waterlogging. Already, an area of cropland and grassland approximately the size of Maine is becoming barren wasteland each year, and the spread of desert-like conditions is likely to accelerate.
>
> Atmospheric concentrations of carbon dioxide and ozone-depleting chemicals are expected to increase at rates that could alter the world's climate and upper atmosphere significantly by 2050 . . .
>
> Extinctions of plant and animal species will increase dramatically. Hundreds of thousands of species - perhaps as many as 20 percent of all species on earth - will be irretrievably lost as their habitats vanish, especially in tropical forests.
>
> The future depicted by the U. S. Government projections, briefly outlined above, may actually understate the impending problems.
>
> Indeed, the problems of preserving the carrying capacity of the earth and sustaining the possibility of a decent life for the human beings that inhabit it are enormous and close upon us. . . The available evidence leaves no doubt that the world - including this nation - faces enormous, urgent, and complex problems in the decades immediately ahead. Prompt and vigorous changes in public policy around the world are needed to avoid or minimize these problems before they become unmanageable. Long lead times are required for effective action. If decisions are delayed until the problems become worse, options for effective action will be severly reduced.

The implications of these projections are ominous. If even some of these predictions come true, life for every person on the face of the earth will be decidedly poorer than it is today. The effects of disastrous resource calamities elsewhere in the world will be felt even in countries like the United States. Imagine the economic and political costs involved with ever increasing energy shortages, loss of agricultural lands, increased atmospheric pollution, and immigration pressures. The above costs do not even consider the obvious deterioration of life for human beings associated with rampant extinctions of plants and animals, water shortages, less living space per person, and the very real threat of losing more and more citizen freedoms as a function of ever incresing restrictions on personal behavior. These problems and potential problems simply will not go away by ignoring them. They must be addressed directly and courageously if present and future generations of the world community are to have a quality of life even close to that enjoyed by citizens in developed nations today.

Well Then, What's the Answer?

The answer lies in something called "environmental literacy". This somewhat glib term stands for a set of human attributes which would help human beings resolve current issues and provide them with the skills needed to cope with future ones. Earlier, a number of international EE objectives (Tbilisi Conference Objectives) were

referred to as setting the stage for defining EE. However, these objectives are far from operational. Realizing this, a team of professionals from Illinois, Wisconsin, and Michigan set about to translate these objectives into goals for curriculum development in EE. These goals were subsequently published in the Spring 1980 issues of the Journal of Environmental Education, pp. 42-47.

From these curriculum goals the senior author of this methods text, working with Dr. R. Ben Peyton of Michigan State University, set about to produce a set of "literacy components for EE". Included in these literacy components is what is referred to as a Superordinate Literacy Component and four subordinate ones, each with several parts. The "Environmental Literacy Components" are as follows:

Literacy Components

The Superordinate Component: The environmentally literate citizen is able and willing to make environmental decisions which are consistent with both a substantial quality of human life and an equally substantial quality of the environment. Furthermore, this individual is motivated to act on these decisions either individually or collectively.

> Comments on the Superordinate Literacy Component: It should be noted here that many people get confused when one speaks of "quality of human life" on one hand and "quality of the environment" on the other. Whether or not a society can have it both ways is really a moot issue. Humans have reached a crossroads in environmental destiny where almost any decision made is seen as a compromise between these two variables. There are simply too many human beings on the face of the earth to maintain either a desired quality of life for all peoples or an environment free of degrading influences. Therefore, most environmental decisions somehow compromise people or the environment or both. Of course, this leads to all sorts of moral and ethical questions which will remain unaddressed at this point. The fact remains, however, that "quality of life" and "quality of the environment" must both be seriously considered in any environmental decision making process.

Subordinate Literacy Components: These are the components which exist beneath the superordinate component discussed above.

Literacy Component I - Ecological Foundations: At this level, the receiver (learner) has sufficient knowledge of ecology to permit him/her to make ecologically sound decisions with respect to both humans and the environment.

Although it is difficult to pinpoint exactly that ecological knowledge which is critical and prerequisite to sound environmental decision making, certain key concepts and allied ecological principles appear crucial. Therefore, the writers believe that the principles associated with the following concepts need to be understood in order to permit the application of the principles to environmental decision making.

A. Individuals
B. Populations (Population Dynamics)
C. Interaction
D. Interdependence
E. Limiting Factors
F. Energy Transfer
G. Biogeochemical Cycling
H. The Community
I. The Ecosystem
J. Homeostasis
K. Succession
L. Man as an Ecological Variable

Literacy Component II - The Awareness of Issues and Human Values: This component, like the previous one, seeks to provide the learner with information. Rather than ecological information, however, this component deals with a wide variety of so-called environmental information. Again, it might be said that this information or knowledge is prerequisite to the actual investigation, evaluation, and remediation of issues.

The environmentally literate person then, at this level, understands (conceptualizes) . . .

A. . . . the way in which human cultural activities impact on the environment. Here, cultural activities would include economics, religion, politics, social customs, etc.

B. . . . the way various individual behaviors impact on the environment.

C. . . . a wide variety of environmental issues and both the ecological and cultural implications of these issues.

D. . . . the various alternative solutions available for solving (or partially solving) discrete environmental issues. Of critical concern here would be the ecological and cultural implications of these various solutions.

E. . . . the need for thoroughly investigating and evaluating issues prior to taking environmental action.

F. . . . the roles played by differing human values in environmental issues. Also, an understanding of the genesis of these varying values appears crucial.

G. . . . the need for personal values clarification as an integral part of environmental decision making.

H. . . . the need for responsible citizenship action in the solution of environmental issues.

Literacy Component III - The Investigation and Evaluation of Issues and Solutions: This component, unlike the previous two components, goes beyond the acquisition of information per se. Level III deals with the development of those skills necessary for the actual investigation and evaluation of environmental issues. Further, it provides for the evaluation of alternative solutions for solving issues.

The environmentally literate person then, at Level III, has those skills enabling him/her to. . .

A. . . . identify and investigate environmental issues using both primary and secondary sources of information.

B. . . . analyze environmental issues with regard to the various perspectives associated with those issues. Further, the receiver is able to identify the ecological and cultural implications of these value positions.

C. . . . identify alternative solutions for discrete issues and the value perspectives associated with these solutions.

D. . . . evaluate alternative solutions for discrete issues with regard to their ecological and cultural implications.

E. . . . identify and clarify his/her own value positions related to discrete issues and the solutions proposed for those issues.

Literacy Component IV - Citizenship Action: This component deals with those skills necessary for learners to take appropriate environmental action.

The environmentally literate person, at Level IV, has those skills enabling him/her to. . .

A. . . . take either individual or group action (i.e., persuasion, consumerism, political action, legal action, ecomanagement) where appropriate for the purpose of solving or assisting to solve particular issues.

B. . . . evaluate actions taken with respect to their impact on quality of human life and quality of the environment.

Literacy, then, begins with knowledge and ends with action. Although these literacy outcomes are, by and larger, hierarchical in nature, there are many instances where two or more components or subcomponents can be acquired simultaneously, e.g., certain ecological knowledge and issue knowledge or issue information and the alternative methods of investigating those issues. In fact, to assume that each literacy component or subcomponent must be acquired independently of others is probably educationally unsound. There is far too much overlap between many of them. Therefore, although hierarchical in nature, environmental literacy outcomes are interdependent and should be learned in a manner which is logical and defensible.

Ben, Do you think that duck has an opinion on oil slicks?

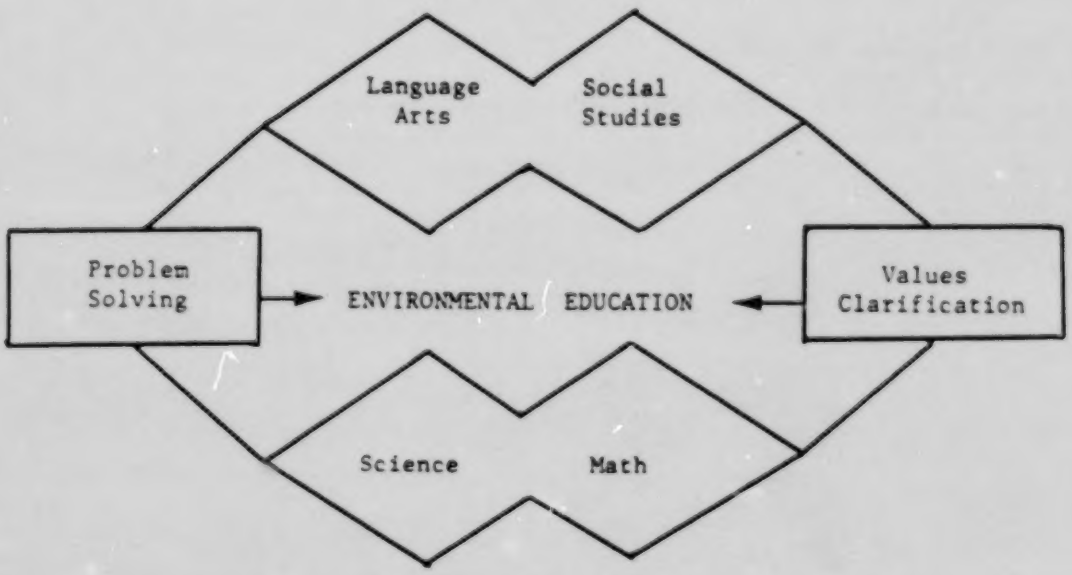
Where Does EE Fit?

A review of the "Environmental Literacy Components" just presented should make it very clear that EE intersects with a number of traditional content areas. Literacy Components II A, C, & H are sharply related to the social studies. Component III A is traditionally a language arts component. Thus, EE does not fit any one traditional discipline. Does this mean, then, that EE should be a separate course in the curriculum?

Although some schools - particularly at the middle school level - offer a separate course in environmental education, most schools find it hard to fit another course into an already crowded curriculum. This results in either forgetting about EE completely (which is often the case) or using what is called an "infusion model". In the infusion model, EE is incorporated (i.e., infused) into existing courses. Thus, it is incorporated into science, language arts, social studies, and even math. In the higher grades it is sometimes infused, very effectively, into home economics and agriculture and, to some extent, into art and music as well.

Using the infusion process the language arts teacher, for example, could teach library skills using environmental issues as the focus for that research. Research papers could be assigned which permitted the student to select an issue of particular importance to him/her, investigate that issue using secondary sources, write the paper and, perhaps, report on the research to the entire class.

The case for infusing EE into the social studies is outstanding. Environmental issues are, by and large, a function of man's manipulation of the earth's resources. The use and abuse of space, air, water, soil, plants/animals, minerals, etc. results in situations which end up in disagreements. An example might be rezoning crop-producing land for a shopping center or a subdivision (this happens constantly). Economic and sometimes political values lie behind the "development" of agricultural land while conservationists/environmentalists value the



retention of croplands simply because we are losing them at a phenomenal rate. These divergent values meet head-on in controversy. Thus, an issue is born. Since the issue is man-centered, the social studies offer a sound rationale for the study of environmentally-related issues.

The infusion of EE into the science program is, by far, the most common infusion practice. The logic for infusing EE into science does have considerable merit since the earth's resources are, in large part, directly related to science interests. Knowledge concerning mineral resources, for example, is largely a function of geology. Atmospheric phenomena are strongly allied to chemistry and meteorology. Population dynamics and a host of other critical variables are related to ecology and so on.

Earlier in this methods book you were introduced to the goals for science education as identified by Project Synthesis. Here too is a strong case for infusing EE into science because Project Synthesis calls on science teachers to focus, in part, on science-related social issues. Environmental issues are, indeed, science-related.

Mathematics can also play a role in EE. Math skills are brought to bear on numerous problem solving activities in EE. How can one manipulate population data, for example, without using math skills? Math must be applied in surveys, questionnaires, and opinionnaires, all tools for environmental investigation.

Infusing EE into a school's curriculum is not an easy task, particularly if the EE program is to have substance and continuity. The problems are numerous. What is to be taught at a particular grade level? Are the school's teachers amenable to the infusion strategy? Do the teachers have the skills? Can inservice education be provided? Is there a curriculum for EE available? If not, can one be prepared? How will students be evaluated, particularly with respect to terminal objectives? How can community resources be brought to bear on the program? There are certainly no easy answers to some of these questions. Even so, the writers believe that infusion is the best possible answer for EE.

A rationale for an infused EE program was recently proposed by the senior author of this methods book and Dr. R. Ben Peyton of Michigan State University. This rationale is as follows: "The infused EE program . . .

> (1) . . . will reach more students across more grade levels (if environmental education is to be truly a life long process, infusion appears to be the best possible vehicle with which to accomplish this.),
>
> (2) . . . will not require placing a new course in an already burdened curriculum.
>
> (3) . . . better demonstrates to students the tremendous complexities involved in environmental problems [issues], and
>
> (4) . . . should result in a much greater application of environmental knowledge, skills, and attitudes on the part of individual students at the citizenship level."

Achieving Literacy! What Is Involved???

As was stated earlier, EE literacy begins with knowledge and ends with action. Seems like a simple enough idea, right? The problem is, it isn't simple at all.

Space does not permit a thorough analysis of what is known about achieving the ultimate goal of EE - the development of a citizen who is able and willing to make sound environmental decisions and act on those decisions. It may be enough to note that what is known is terribly complex and what has yet to be learned is substantial. Nonetheless, there are some "rules" or principles involved of which the elementary teacher should be aware. This section is a meager - but entirely honest - attempt to introduce you to some of these.

First of all, knowledge about issues - in and of itself - is not enough to promote responsible citizenship behavior with respect to solving environmental issues. The reliance on knowledge to get the job done is commonplace in EE. Yet, most research shows that an awareness of issues (i.e., simply knowing about them) is insufficient in terms of changing behavior. There is some evidence, on the other hand, that indicates that an indepth investigation of an issue may promote changes in human values and lead to overt action with respect to that issue - at least with some individuals. However, in this instance, the investigation or information input must be thorough and fairly exhaustive.

Secondly, a person's perspective about an issue depends heavily upon his/her beliefs. A belief is nothing more than an idea that a person holds to be true. A belief may or may not be accurate, i.e., it may or may not be substantiated by reality. If the belief is erroneous, the individual's values and attitudes (and more) can be biased in an ecologically faulty manner. The idea that, "Having three or more children poses no environmental threat" is a belief statement. It describes what an individual perceives to be reality. In this case, the belief is probably wrong. It does not describe a true relation between family size and ecological stability (from a population dynamics perspective). It goes without saying that it becomes important for the environmental educator to provide information concerning issues that is both accurate and thorough. More on this later.

Third, how a person feels or behaves with respect to an issue is closely related to his/her values. A value, here, is defined as the relative worth an individual places on something. The comment, "Large families are both beautiful and desirable" implies, perhaps, both aesthetic and social values placed on large families by the individual. Note that the value component is different from the belief component although, in this instance, they are compatible with each other.

Fourth, attitudes are also involved in this analysis of the task of achieving environmental literacy. And, attitudes are difficult to define because they are complex entities. Let us define an attitude as a complex mental construct (perception) which emerges out of an integration of an individual's belief and value systems. Attitudes are also characterized as perceptions that predispose an individual to behave in certain ways. This, however, is open to argument in that an attitude which has not fully matured, or of which the individual is not fully conscious, may not produce a particular behavior. In any event, attitudes are typically considered to have knowledge, emotional (affective) and behavioral components.

Thus, attitudes may often be considered as perceptions or complicated mental constructs that result from a personal integration of beliefs, values, and behaviors. Just how these components interact with each other is uncertain - researchers are just not sure how the variables interplay. Even so, we do know some things that are important. For example, an individual may reject new information out-of-hand if it disagrees with a strong value perspective or belief system which has been handed down by a loved or respected parent/friend. An individual who has strong anti-abortion beliefs and values will probably reject the idea that abortion is an important contribution to population control. Those who reject abortion may well turn to arguments like chastity, sex education, birth control, or adoption of unplanned offspring as the only viable alternatives to abortion even though there is a mass of evidence that indicates that chastity is largely a moot issue, few readily available contraceptives are foolproof and many adolescents and young adults will not turn to them for protection, and adoption still places an additional child into the population. In other words, social forces may well dictate attitudes irrespective of enormous bodies of knowledge which would indicate a need for alternative beliefs/values/attitudes.

Let us take this integrative process one step further. Generally, values impinge upon attitudes to a greater degree than knowledge (beliefs). We already know that values are used to screen new information that may be modified or rejected as a function of those highly-prized values. If attitudes/behaviors are to be changed in the case of a highly volatile issue, some form of dissonance must be perceived by the individual regarding irreconcilable differences between his/her beliefs and values. In the case of population, the individual must come to value human population stability and the ecological implications for same. If such a value can be internalized, new information supporting that value will be processed and integrated into the attitude which predicts behavior. How is this accomplished? We are not certain! What is certain is that, with an issue as volatile as this one, the evolution of new attitudes may be hard to come by. The answer probably lies in a close inspection of personally-held values (value clarification) combined with accurate and fairly thorough information concerning

a broad spectrum of topics, e.g., population dynamics, human population projections, immigation problems/patterns, birth control, cultural biases toward family size, ecological implications of eruptive populations, etc.

It goes without saying that, in order to promote appropriate attitudes/behaviors, environmental educators must deal with the beliefs and values of students. This is a real problem when we realize that each learner has a unique set of beliefs and values which results in a very personal frame of reference concerning an issue or group of issues. Further, indoctrination of students is undoubtedly counterproductive. To directly confront a student's value system will probably result only in a deepening commitment to previously held values. In addition, indoctrination is highly unethical. In a democratic society, educators must strive for honesty in instruction and the development of effective problem solvers and participatory citizens. If teachers help students to become skilled problem solvers (e.g., investigators and evaluators of environmental issues) the students will probably sort through their own values with respect to environmental concerns and, in almost all cases, line up on the side of environmental integrity. The reader should note that these words are more than just "catch-phrases" in education; there is evidence that this prescription does, in fact work.

Fifth, how a person behaves is related to a phenomenon called locus of control. Locus of control is a factor associated with an individual's perception of whether a particular behavior will result in an anticipated reinforcement for doing (acting). This is called expectancy of reinforcement.

Some individuals believe that they are in control of situations that demand action. These individuals have a high expectancy of reinforcement. Such people are said to possess an internal locus of control. Internal locus individuals would tend to take action on an issue because they feel that their actions would, in some way, help alleviate the issue.

On the other hand, some individuals believe that they are not in control. Therefore, they have a low expectancy of reinforcement. These individuals are said to have an external locus of control. This simply means that the control over a situation lies external to the individual - at least, the external individuals believe that. External people may, for example, believe that "powerful others" are in charge and will dictate the outcome of a problem or issue.

Going back to the population issue for a moment, let us take a look at locus of control in that context. Who, for example, would you expect to use birth control methods while engaging in coitus? Yes, you would expect birth control to be utilized widely by people who felt in control of conception. And, research indicates that you are right! Internals tend to use contraception while externals tend not to.

Are internals and externals consistently one way or another? Research is unclear on this point although we know that some individuals have a marked external nature while others reflect an internal nature. But, there is also some evidence that indicates that people may be internal in certain situations and external in others. There is also some evidence that indicates that some individuals can, indeed, be motivated to move from an external perspective to an internal one. If this is correct, there are important implications here for EE. Although it is unclear precisely what factors are involved in such a change, it is probably that an external will move toward an internal perspective if he/she:

(1) understands the issue in depth, (2) believes that action is called for, and (3) knows what action is going to maximize the possibility of exercising control over the outcome. If this is correct, environmental educators should focus on crucial issues (rather than ones typically considered), delve into issues in depth, and provide training in citizenship action skills that can be applied to those issues.

Sixth, an individual who has a high degree of sensitivity toward the natural environment is more prone to deal with the environment in ecologically appropriate ways than others. The sensitive individual (all other things being equal) is the one who . . . refuses to litter highways and natural areas . . . conserves natural resources . . . works to preserve ecologically important natural areas . . . strives for ZPG . . . respects hunting and fishing laws . . . insists on rational zoning requirements . . . etc.

What is environmental sensitivity? It is, by and large, an empathetic or understanding view of the environment. It is a view that respects ecological integrity and one that believes that Man must live, somehow, in ecological harmony with the natural environment.

If sensitivity is such an important variable, why not focus on it solely and change the perspectives of every youngster in the schools of the world? Unfortunately, this is easier said than done. A high degree of sensitivity seems hard to come by. Research, again, indicates that the very sensitive individual is one who grew up closely allied with a natural setting and spent considerable time in that setting - or, experienced the loss of a highly regarded environment, e.g., a much-loved forest being cut down to make way for a shopping center. Some sensitive individuals report another variable as being crucial. That variable is associated with role models. The person(s) who acted as the role model(s) demonstrated a high degree of sensitivity that was emulated by the recipient of that experience. Role models were often members of the immediate or extended family. In a surprising number of cases, the role model was a teacher.

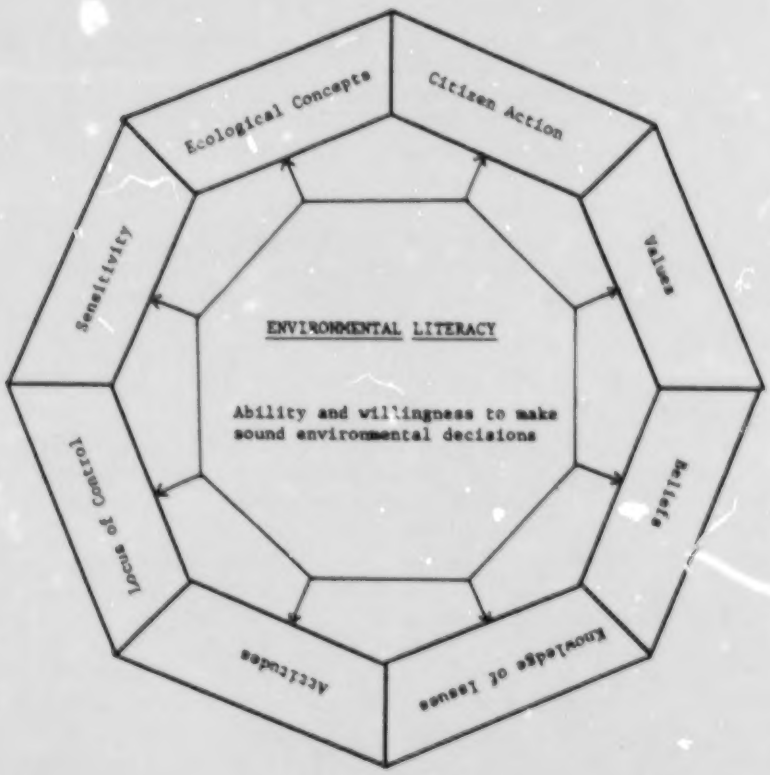
Being that teachers were sometimes reported to be precursers to sensitivity, there is some opportunity for the development of sensitivity by teachers. However, the teacher would have to fit the sensitivity model rather well, reflect it diligently, and have such a positive relationship with students as to make them eager to associate with that posture. How many teachers are willing to express that level of dedication to their charges? Probably only a few will be so inclined. Thus, it becomes obvious that the school is situated so as to have relatively little control over the development of intense environmental sensitivity. This may, in part, be an ominous sign.

Seventh, there is some evidence to indicate that individuals who are knowledgeable about environmental action strategies and skilled in applying them will, in fact, use them in an effort to remediate issues. We are not certain as to the entire meld of variables associated with this phenomenon but it appears to be an important one. If, in fact, students can be taught about citizenship actions and trained in their use, more citizens would eventually confront environmental issues. Unlike sensitivity, environmental action can be taught in the classroom. This has been demonstrated numerous times by both teachers and researchers interested in EE. The teaching of environmental action in classrooms across the nation could well be the key needed to unlock the door to some semblance of environmental integrity, nationwide.

Eighth, and lastly, a knowledge of basic ecological concepts seems to be an imperative in the development of environmental literacy. Although this may seem, on the surface, to be an unimportant variable, it may be pivotal to the entire process. Why?

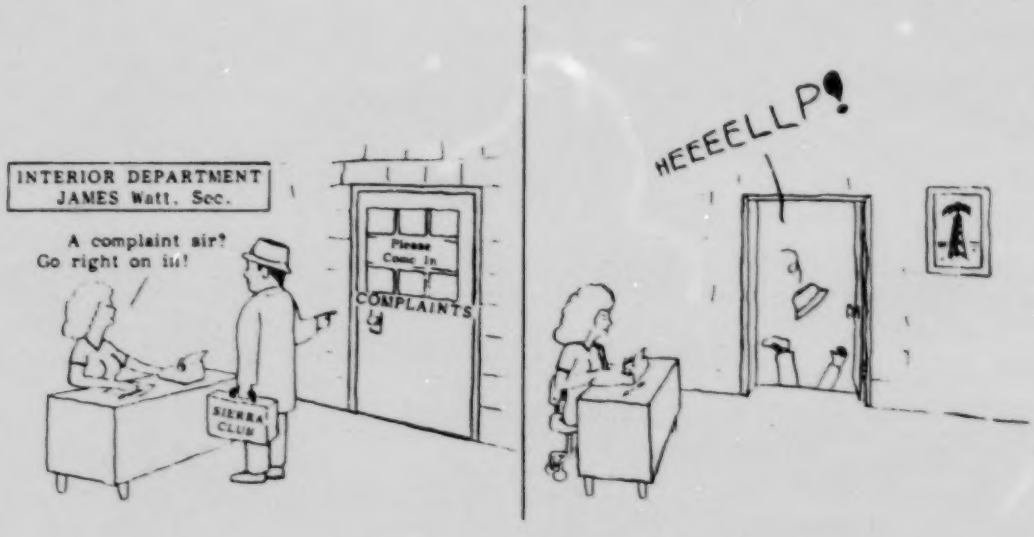
When an individual makes a decision concerning an issue, that decision will have ecological consequences if carried out. Thus, it is imperative for the individual to be able to assess the ecological consequences of a given decision. You may recall that, earlier in this chapter, the superordinate goal of EE was presented. This goal states that environmental decisions should be made which are consistent with both a quality of life and an equally substantial quality of the environment. Environmental quality is, in large part, dependent upon the ecological integrity of that environment. Thus, ecological concepts become crucial to the decision-making process. A listing of several of these concepts can be found under Literacy Component I described earlier in this chapter.

IMPORTANT VARIABLES ASSOCIATED WITH ENVIRONMENTAL LITERACY



This figure illustrates the important variables associated with environmental literacy which are discussed in this section. Note how each of these is shown to interact with all others. Although research has not revealed the exact nature of these interactions, they most certainly do occur.

The eight variables discussed in this section are ones which appear to be, both individually and collectively, crucial to environmental education. These are, in order of presentation: (1) knowledge of issues, (2) beliefs concerning issues, (3) the individual's values, (4) a person's attitudes, (5) locus of control, (6) environmental sensitivity, (7) knowledge of and skill in environmental action strategies, and (8) ecological concepts. Exactly how these variables interact with each other is unknown. However, the crucial nature of these eight conditions must not be ignored and kept out of the classroom simply because we do not know for sure how they interact. What is known, however, is that certain of these, by themselves, will not result in an environmentally literate citizen. Attention should probably be given to all eight with an emphasis placed on beliefs, values, and action.



More on Values - The Role of Values Clarification

In the past few years, values clarification has received a good deal of attention in the United States. Proponents of values clarification believe that the clarification process has numerous benefits for students. Among these are: (1) to make the individual more purposeful, (2) to help students sharpen their critical thinking skills, and (3) to help people have better interpersonal relations. Values clarification is often recommended for use in areas such as environmental education, sex education, career eduction, drug education, and religious education.

As you might suspect, values are a function of a person's sociocultural background. This, of course, includes belief systems and the knowledge associated with those beliefs. Research in EE does indicate that, at times, new knowledge will influence values. Research also dramatically shows that when a student completes an indepth investigation into an issue, that investigation can result in either the modification of existing values or the attainment of new value positions or both.

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Environmental literacy is very dependent on the individual continually evaluating personally held values. This evaluation should go on continuously, prompted by new information or new experiences with the environment. Teachers can stimulate a more rapid evolution of personally held values by providing information and experiences designed to do exactly that. This, of course, infers that the professionals doing the stimulating probably hold some preconceived notion about the direction in which those values should evolve. Although there are those who would argue against this inference, it is probably, in the final analysis, true.

As teachers, we would like very much to be able to provide settings in which we remain entirely neutral as far as students' values are concerned. But, we know full well that our biases will eventually creep into both the process itself and the setting within which that process is taking place. As noted earlier, the authors believe that an environmentally literate human being is one who is willing to maintain an environmental ethic consistent with ecological stability. This value represents a philosophical bias, regardless of how defensible it is! Values clarification activities produced by the authors try to nudge the student in that direction. Certainly, we do not apologize for this admission. We simply wish to make the very important point that the so-called "neutrality" which the educator is supposed to represent probably does not exist - even under the best of circumstances.

In the traditional sense, values cannot be taught. When people go through the process of values clarification they do so in a very private and personal manner. No amount of preaching or intimidation will make a person truly accept a value position. Of course, students might verbalize a particular value, or behave as if they had that value in order to avoid ridicule or punishment. But, this mode of behavior is artificial and will be reversed as soon as the threat is removed. The values that count are those that human beings accept and act on freely and consistently. Therefore, it is crucial that the teacher attempt to promote an educational climate in which values can be chosen freely from available alternatives, tested against logic, and acted on. We call this educational climate a "value fair" setting, i.e., a setting in which values can be communicated, tested, and clarified without fear of ridicule.

A number of values clarification activities for EE exist. Values can often be inspected and clarified as a function of inquiry strategies, although other strategies also exist. For example, numerous discussion activities lend themselves well to values clarification. Questioning is critically important in these discussion activities. Depending upon the situation, questions like the following might be used:

- Why did you answer as you did?
- Should you or the class get involved in this issue? Why?
- What is the problem? Why does it have environmental importance?
- Why do you prefer one alternative over the other?
- Do you think your choices are the best possible? Why? Why not?
- What are your own priorities concerning technological expansion?
- What are your priorities for the environment? Are your environmental and technological priorities compatible? Why? Why not?

Many activities are surprisingly easy to conduct and yet yield some very serious thinking on the part of students. An activity such as the one which follows might prove helpful.

A Problem for the Johnsons

In 1968, Mr. and Mrs. W. R. Johnson purchased a home on the outskirts of Bigsville for $29,850. Over the next few years, land and building values increased so that the Johnsons felt perfectly comfortable when they finished the basement and added a garage and a workroom for Mr. Johnson.

In 1972, the Bigsville Airport Authority condemned nearly 1000 acres of land just a mile or so north of the Johnson home. In 1976, an international airport was in service where there had been only farm land before. The Johnsons found that the north-south runway was due north of their home. The noise was awful.

Since the development of the airport, highway construction and traffic has increased over 100 times. Noise levels are, in the entire area, a serious environmental problem. Crime has increased over 250% and property values have decreased greatly. Today, the Johnson residence is barely worth $32,000 even with the additional money invested and a high rate of inflation. In another area, their home would be worth up to $60,000.

The biggest problems for the Johnsons are economic and psychological. The Johnsons did not anticipate living near a jetport, nor did they anticipate an increase in crime and noise levels. Certainly, they did not anticipate a tremendous decrease in property values.

Possible Questions:

1. What were the values that might have been held by the Bigsville political leaders who chose to construct the airport in the first place? Do you think that their values were the same as the people living around the area taken over by the airport? Why?

2. What options are available for the Johnsons? What positions do you think the Johnsons should take with authorities in this situation? Why?

3. What responsibilities, if any, does the Bigsville Airport Authority have in this situation? Why do you think so?

4. Assume that the entire area was equally disturbed by the airport. Would an environmental action citizens' committee be able to help? How would such a group go about getting something done? What if the committee finds out that the only hope is to

conduct itself in an illegal manner? Should they continue their efforts? Why? Why not? What values would be reflected in the decision?

5. Is there a "way out" of this situation for the Johnsons? If so, what alternatives do you think they might have? Which of these alternatives might prove most effective?

The value of the above activity is, in part, determined by the teacher's ability to ask those questions that probe the students' values and give them an opportunity to inspect the bases of those values. Excellent class discussions can result from such an anecdote and the teacher must be cautious in deciding to what extent to permit the discussion to "heat up" if there are sharp differences of opinion (differing values) across the class.

Now, what about some of your own environmental values? The following activity has been designed to demonstrate the divergence of values that can exist in both preservice and inservice teacher populations. It has been used many times with success. Please complete this brief activity, following directions carefully.

Let's Compare Values

This activity is designed to let you compare a few of your environmental values with those of your peers. On the next page you will find a list of eight statements with which you may agree or disagree. Following each is a number line ranging from "strongly disagree" to "strongly agree". You are asked to circle the number of the response which best reflects how you feel about the statement. Please do this before going on to the rest of the activity.

1. The killing of deer by hunters is an important part in keeping deer herds healthy.

X	X	X	X	X
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

2. The great whales don't belong to any nation and, therefore, any nation that wants to hunt them should have the right to do so.

X	X	X	X	X

3. Human females should not be allowed to have more than two children.

X	X	X	X	X

4. Although landowners hold title to farm land, there should be regulations which guarantee that farm land will <u>not</u> be converted to non-agricultural purposes.

X	X	X	X	X

5. The recycling of metals such as aluminum and steel should be mandatory even if it is not always profitable.

X	X	X	X	X

6. Air pollution standards should be relaxed in order to get better gas mileage in automobiles.

X	X	X	X	X

7. Only those people who live alone or have special problems should be allowed to keep a dog or a cat because of the tremendous amount of food energy consumed by pets.

X	X	X	X	X

8. Nuclear power plants should continue to be built in order to produce needed electrical energy.

X	X	X	X	X

On this page you will find a summary chart. After everyone in class has responded to the items on the previous page, add up the class responses in each category for that statement. This will clearly show whether there is a wide variation of values within the class on a given statement. If this proves to be the case, a discussion might determine the reasons for this observation.

Summary Totals

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				

Postsummary Discussion:

1. Analyze those statements for which there are wide differences of opinion. Why do these differences exist? What are the logic bases for these value positions? Are these value positions ecologically sound? Why? Why not?

2. Sometimes a group will tend to load on the "neutral" category. When this occurs, what might be the reason? Could this circumstance be changed through education? If so, how?

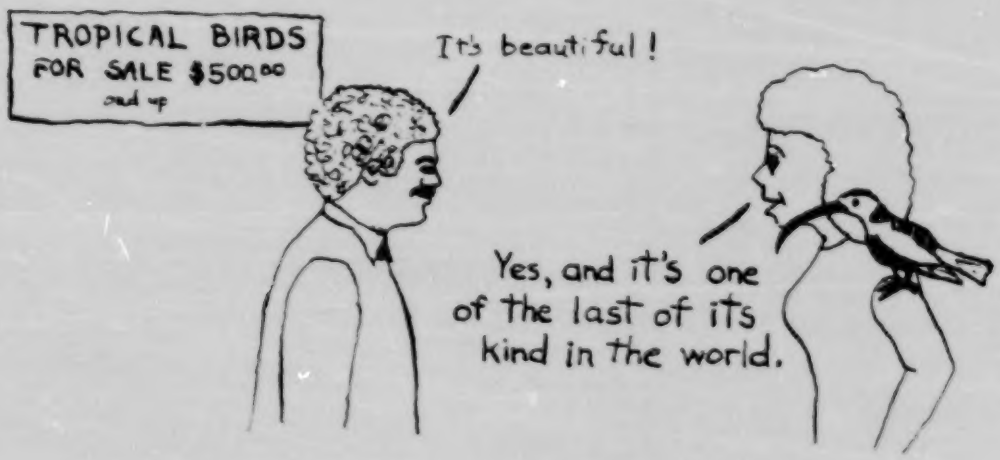
3. Why is it difficult to resolve an environmental issue where there are strong and differing value positions?

A Look at Conflicting Beliefs and Values

As noted earlier in this chapter, attitudes and behavior are very complicated entities that often emerge from an integration of an individual's belief and value systems. And, of course, it is quite appropriate to think that beliefs and values modify each other to a considerable extent. As you might expect, this interplay can do some strange things to a person's attitudes and behaviors. One of the most interesting phenomena revolves around inconsistencies in the belief-value perspectives of an individual. These inconsistencies often result in certain attitudes and behaviors in some situations and others in other situations.

For example, a duck hunter may believe that canvasback ducks are a threatened but desirable species of waterfowl and shoot only one per day as the law allows. Conversely, this same hunter may shoot an extra mallard or two - over the legal limit - because they are not threatened and, in fact, quite common in the region. Thus, the hunter basis his shooting behavior and his waterfowl values on whether he believes a species is threatened or not. In this case, the important variable is not the law at all but differing beliefs concerning the two species of waterfowl. What might be critical to this situation is a lack of knowledge concerning the very rigorous way in which wildlife biologists go about deciding how much hunting pressure a species can endure and still retain a viable breeding population from year to year. Given this information, the hunter might take on a new belief system and a different set of values, resulting in a new attitude and a different (legal) behavior concerning mallards.

Let us inspect our own beliefs/values in a setting far removed from duck hunting to see if they are consistent throughout. The issue is population control. The activity begins on the next page.



Are My Population Values Consistent?

A Values Clarification Activity

Part I

Directions: Rank order the following population control measures with respect to your own values concerning appropriate ways to alleviate the population problem. The one you rank No. 1 would be the measure you value the most.

	Rank	Measures
A.	____	distribute birth control information widely, beginning with citizens of approximately high school age.
B.	____	toughen up the moral fiber of all segments of society via the home, the church, etc. to reduce casual sexual behavior.
C.	____	legalize abortion for all females everywhere.
D.	____	trust the common sense of individuals to limit family size.
E.	____	limit each family to two children and enforce said limitation - via sterilization if necessary.

Now, having completed Part I of this activity, turn this page upside down and complete Part II. Directions will be provided.

Part II

Directions: Rank order the following population descriptions according to how you would value those situations. The situation you would value the most would be No. 1.

	Rank	Description
A.	____	a planet without any human population restrictions whatsoever.
B.	____	a planet with a replacement level (natality) equal to the rate of loss (mortality).
C.	____	a planet with a replacement level (natality) less than the rate of loss (mortality).
D.	____	a planet that is slowly but surely working toward zero population growth (ZPG).
E.	____	a planet with a human population no more than 1.5 times the present population.

Questions:

1. Which value positions in Parts I and II, if any, are consistent with each other?

2. If you ranked D in Part I highly, would this value be consistent with B or C in Part II? Probably not! Why? Your best bet might be to rank E in Part I highly if you valued B or C in Part II. Again, why?

3. Are there any other items in Parts I and II where inconsistencies could be observed? If so, where might these occur? Oftentimes, people are inconsistent in their thinking. What are some of the reasons for this phenomenon related to the population problem? What might be done to correct the problems?

Investigating Issues: A Crucial Literacy Component

You will recall that one of the four Environmental Literacy Components outlined earlier dealt with the investigation and evaluation of environmental issues. Although this literacy component is seldom successfully achieved in today's schools, it is probably crucial to literacy as defined here. Why?

The successful and indepth investigation of issues by students provides them with a holistic view of issues which cannot be duplicated by other means. When the student gathers and analyzes information, he/she assumes an ownership of that information which is impossible to accomplish via a lecture or textbook approach. Further, information collected by the student from a variety of sources tends to transcend the biases of singular information sources. Thus, the student can compare information sources and separate the "wheat from the chaff", drawing realistic conclusions and making evaluation judgements about issues which are probably accurate and defensible.

The authors of this worktext have been engaged in research which focuses on issue investigation for a number of years. This research has clearly demonstrated that middle school youngsters who have been trained in investigation skills can perform magnificently in the investigation arena. Furthermore, these students attain a level of expertise on issues which is far in excess of the teacher's own level of information. In fact, the authors and the teachers of these young people have often learned a great deal about issues by interacting with the students who have completed indepth investigations.

A question may arise concerning the issues which are to be investigated. If one assumes that some issue awareness has preceded the investigation stage and that the teacher has carefully focused on crucial environmental issues (e.g., population, land use management, energy, endangered species, toxic waste disposal, etc.), one has little to fear with regard to the issues the students will choose to investigate on their own. The bottom line is simply to permit the students to select the issues they will investigate after becoming aware of issues and being trained in investigative skills.

Students will not always select the most pressing issues to investigate. This is perfectly alright in that every student should not be expected to be interested in the most crucial issues (for investigation purposes). Over the years, a wide array of topics have been chosen by students between the grade levels of fifth and eighth. A few of these are:

Wild Horses in the American West
Fur Seals
Wolves
Water Loss in the School From Leaky Faucets
The Great Whales
Water Pollution
The Tuna/Porpoise Controversy
Whooping Cranes
Nuclear Power Generation
Abandoned Automobiles
Recycling Habits of Community Residents
The Alaskan Pipeline
Solid Waste Management
Wilderness Preservation
The California Condor
Reclamation/Surface Mining

The list above represents a broad spectrum of issues or issue-related topics. One might question this particular selection of issues but it should be remembered that these were the issues chosen by the students - ones they wished to investigate. In addition, research has shown that animals are of extreme interest to preadolescents and this may account for the numerous topics dealing with endangered species.

More importantly, perhaps, are the skills associated with the issue investigation. In learning how to investigate issues, students acquire a set of skills which are very sophisticated and can be broadly applied in a variety of settings - even beyond the confines of environmental problems. These skills are reflected in the objectives set forth in a set of modules designed to provide investigation skill training. A few of the more important objectives are found listed below. You may be surprised when you read this list of objectives and realize that children as young as fifth graders have received this training.

Sample Objectives

1. . . . compare two different information sources and communicate how they differ.

2. . . . identify governmental or private agencies which can be written to for specific information.

3. . . . write letters requesting specific information.

4. . . . identify value positions expressed in environmental news articles.

5. . . . summarize environmental news articles (or other information sources).

6. . . . locate information references in the card catalog.

7. . . . locate information sources in the Readers' Guide.

8. . . . communicate the rules that tend to govern the use of surveys, questionnaires, and opinionnaires.

9. . . . identify issues that can be investigated using surveys, questionnaires, and opinionnaires.

10. . . . design surveys, questionnaires, or opinionnaires as needed.

11. . . . identify conclusions which are appropriate for research data.

12. . . . write inferences which are logical and based on observations.

13. . . . write recommendations which are appropriate for particular research findings.

14. . . . evaluate conclusions, inferences, and recommendations written by others.

15. . . . contract with the instructor for the completion of an issue investigation - an issue selected by the student and approved by the instructor.

Subsequent to the completion of issue investigation, it is an excellent idea for the teacher to set aside time whereby the students can report on their investigations, display the data collected, and share their conclusions and recommendations with the entire class. Interestingly, there have been times when these investigations have been shared with school administrators, the police, city councils, etc. in an effort to sway authoritative opinion in a manner deemed appropriate by the students. Even more interesting is the fact that the students have, at times, been successful in getting something done, e.g., water conservation practices enacted, abandoned vehicles removed, etc. However, under no circumstances do the authors believe that students should be forced to undertake actions such as these. The decision to take action must be the students' and no one else's. The reason for this is simply a matter of professional ethics. Once environmental action is engaged outside the classroom, the students are conducting themselves as participatory citizens, acting on their own belief and value systems. Thus, the authors believe that the teacher must not superimpose his/her beliefs and values on the student when they are behaving as participatory citizens in the community.

Educating for Citizenship Action

Regardless of how the teacher goes about conducting environmental education, the eventual outcome should be a citizen who is both willing and able to take action in the solution of environmental issues. Unfortunately, there are few programs that actually attempt to develop environmental action skills in students. The reason for this state-of-affairs is not clear but it is probably due to the fact that most EE programs go about the business of making the student environmentally aware with the assumption that this will lead to action. This assumption is incorrect and students should be given direct instruction in environmental action strategies if this is a desired outcome of EE.

Teaching for environmental action should include, among other things, information on the wide array of possibilities that exist for positive action. These possibilities range from individual citizenship action to group action. Further, the power of group action should be stressed in that coalitions of human beings can usually exert more influence than can the individual, working alone. Similarly, group action can vary from that expressed by a student council or a neighborhood coalition to that expressed by international organizations like the World Wildlife Fund or Ducks Unlimited.

Also of great importance are the categories of action and the skills inherent in these categories. These include persuasion, political action, legal action, consumerism, ecomanagement (physical intervention), or combinations of these. Interestingly, every elementary school youngster can get involved in all of these with the exception, perhaps, of legal action. A definition of each of these follows:

Persuasion: . . . an effort to verbally motivate human beings to take positive environmental action as a function of modified values.

Political Action: . . . an effort aimed at persuading an electorate, a legislator/legislature, or executive governmental agency to conform to the values held by the person(s) making the effort.

Legal Action: . . . any legal or judiciary action taken by an individual or group or organization aimed at some aspect of environmental law enforcement or a legal restraint preceding some environmental behavior perceived as undesirable.

Consumerism: . . . an economic threat by an individual or group aimed at some form of behavioral modification in business or industry.

Ecomanagement: . . . any physical action taken by an individual or group aimed at directly maintaining/improving the existing ecosystem.

In addition, emphasis should be given to the important constraints that must be placed on action. These constraints infer that there are some serious questions that must be attended to before an action is taken. The writers of this worktext, working with other curriculum developers in EE, have identified a number of questions that should be answered before an action is decided on. They follow:

1. Is there sufficient evidence to warrant action on this issue?
2. Are there alternative actions available for use? What are they?
3. Is the action chosen the most effective one available?
4. Are there legal consequences of this action? If so, what are they?
5. Will there be social consequences of this action? If so, what are they?
6. Will there be economic consequences? If so, what are they?
7. Are my (our) values consistent with this action?
8. Do I (we) understand the procedures necessary to take this action?
9. Do I (we) have the skills needed to take this action?
10. Do I (we) have the courage to take this action?
11. Do I (we) have the time needed to complete this action?
12. Do I (we) have all of the other resources needed (other than the above) available to make this action effective?
13. What are the ecological implications of this action?

A part of the training students get in environmental action could involve their analyzing the actions of others subsequent to training in action categories, levels of action, and the constraints which should be placed on action. In particular, students should have an opportunity to analyze actions in terms of the key questions listed above.

An example of an anecdote which could be analyzed using these thirteen questions is found on the following page:

Drawing Attention to Nuclear Power

One man's protest against nuclear power plants made headlines on Washington's Birthday. Instead of chopping down a cherry tree, Samuel H. Lovejoy - a twenty-seven-year-old college student and organic farmer - toppled a 500 foot tower being built in connection with a $1.3 billion Northeast Utilities nuclear power plant at Montague, Massachusetts. Unlike the Fox - an anonymous conservation commando who committed acts of vandalism against polluting industries in the Midwest but was never caught - Lovejoy made his point by cutting the guy wires that help up the tower and immediately surrendered to police. In a four-page typed statement, he took full responsibility for the sabotage, which he hoped would set people to thinking about the dangers of nuclear power. He did elicit reactions. Many young people were for him; most conservative New Englanders were shocked, and conservation groups deplored this kind of protest and dissasociated themselves from it.

Taken from the May, 1974 issue of Audubon, page 107.

Interestingly, this anecdote points out that there are some serious questions which can be raised about certain kinds of actions. Not all actions are appropriate.

Whether or not students get involved in environmental action must depend upon the extent to which they are capable, the administrative perspective of the school, and the courage and tenacity of the teacher. Children - in particular those of middle school age - are very able to get involved in issues which are surrounded by considerable controversy. In these situations the teacher can expect some criticism, particularly from those segments of the population which represent values running counter to those of the students.

On the next page you will find a number of actual case-studies of action projects promoted by students and/or teachers. In each case, the categories of action which apply are identified.

Action Case Studies

Action Categories	The Case Study
Persuasion Political Action	Middle school students in southern Illinois become involved in plans to dam a particularly scenic and scientifically rich canyon. Students wrote to government officials at the state and national levels. They prepared editorials for the local newspapers. The canyon was not dammed and they felt that they had a part in the decision making process.
Ecomanagement	Middle and senior high students in a midwestern community became concerned about the eastern bluebird as an endangered species. Over forty nest boxes were constructed in an effort to improve bluebird population levels in the area. All nest boxes were installed on rural university property. Followup observations indicated that the project was a success.
Persuasion	Middle school students in another midwestern school became distraught over the amount of water being lost due to leaky faucets in their school. They took careful measurements and determined that the annual loss cost taxpayers in excess of $100. The students put up a poster communicating their findings (without the knowledge of the teacher) and the faucets were repaired within a twenty-four hour period.
Ecomanagement Persuasion	Students in an eastern urban area became concerned about the depressing environment around their junior high school. They gained permission to landscape the grounds, plant gardens in bare areas, and beautify the area generally. A school-wide campaign was conducted to get students to help protect seed beds and saplings. Community support grows for the project.
Ecomanagement Persuasion	Art students in a Missouri elementary school decided that the exterior of their school was being defaced at an alarming rate. With the cooperation of their art teacher, they got permission to paint murals on the metal panels being defaced and worked to get other students interested in the aesthetic potential of the school site.

An Analysis of Sample EE Strategies

Below you will find two sample strategies which have been widely used in EE. These activities are incorporated here for two reasons. First, you may want to adopt them for use in your own classroom. Second, you are asked to critically analyze these strategies to determine the extent to which each of these incorporates problem solving skills, values clarification, math, science, language arts, and/or social studies.

Activity: Resource Worksheets

A natural place to begin dealing with environmental problems is in the students' own community. Many teachers prefer to have students gather data and come up with their own generalizations concerning specific, local environmental problems or management practices. One technique which successfully involves the student in such investigation is called the "resource worksheet". Students are given data collection worksheets covering one of a number of different environmental topics, e.g., the business district of the community, the city water works, the sewage plant, the garbage dump, or local strip mines. Students collect data individually or in small groups and bring this information back to the class. Numerous extension activities can grow out of this strategy including action projects aimed at improving resource management at the local level. One such worksheet is entitled "The City Water Works". It follows:

City Water Works Worksheet

1. Briefly describe the geographic location of the city water works.

2. What is the source of raw water for the community and where is this source located?

3. Are there alternative sources of water? What are they and where are they located?

4. Make a simple diagram of the flow of water from its source to the final storage tanks. Include each step in the treatment process.

5. Are there any special treatments needed before the raw water is fit for human consumption? If so, what are they?

6. Are the facilities large enough to maintain an adequate supply of water 24 hours a day? What is the evidence for this?

7. In the case of fire or other emergency, is there an adequate reserve of water?

8. Does the water treatment plant have sufficient capacity to meet growing demands for water next year? . . . next two years? . . . next five years? . . . next ten years?

9. Can the source of the raw water supply enough water for the growing demands over these same time spans?

10. What training is provided for the city water works operators?

11. Home owners are charged for the water they use. Is the city using the most economical method for providing water to home owners? What other methods might be available?

12. What problems, if any, do the water works employees identify as being related to local water consumption, supplies, pollution, etc.?

13. Do you have any suggestions as to how you or your class might help solve any existing water resource problems? Might it be possible to sponsor a community water use awareness campaign in order to get home owners to reduce water consumption?

Activity: Determining Water Consumption

The analysis of a person's own water consumption is an excellent follow-up activity to the one described above. This strategy could also be used without the prerequisite of investigating the local water works. In any event, this particular investigation has been used successfully in the intermediate grades. It is a proven values clarification activity and can result in better water management practices in the home.

Determining Water Consumption

How much water do you use? How much water does your family use? How does this compare with other homes in the community? Is this water consumption necessary? How much water could be conserved throughout your community if every home owner and renter chose to use the minimum amount needed for good health and cleanliness? How much could be conserved nationally? These are a few of the questions you can attempt to answer through this activity.

The first task is to determine the weekly consumption of water in your own home. Below you will see a list of uses of water. By carefully observing and measuring water consumption in your own home, complete this computation. (You may need to figure out some interesting ways to make some of these measurements!) Be sure to include all uses you can think of besides those listed here.

Home Water Consumption

Use	Gallons Needed Per Week
Drinking and food preparation	_____
Dish washing	_____
Clothes washing	_____
Car washing	_____
Bathing, showering, general washing	_____
Toilet flushing	_____
Garbage disposal (if mechanical)	_____
Watering grass, gardens, etc.	_____
Water for pets - drinking, bathing, etc.	_____
Water lost from leaking faucets	_____
OTHER _____	_____
Total gallons used per week =	_____

Divide the "Total gallons used per week" by the total number of persons in your home. This will give you the average number of gallons used per person per week. Gallons per person per week = _____

The second task is to determine the minimum amount of water needed for all uses in your home. It is sometimes amazing to discover that considerable water can be saved by changing a few personal habits, repairing leaking faucets, etc. How much is really needed? Compute the minimum needs below:

Minimum Home Water Needs

Use	Gallons Needed Per Week
Drinking and food preparation	_____
Dish washing	_____
Clothes washing	_____
Car washing	_____
Bathing, showering, general washing	_____
Toilet flushing	_____
Garbage disposal (if mechanical)	_____
Watering grass, gardens, etc.	_____
Water for pets - drinking, bathing, etc.	_____
Water lost from leaking faucets	_____
OTHER _____	_____
Minimum gallons needed per week =	_____

Again, divide this sum by the total number of people in your home to get an average. Minimum number of gallons per person per week = _____

At this time subtract the minimum number of gallons per week from the original number of gallons per person per week. This will give you the amount of water than can be conserved per person per week.

How many gallons can you save per person per week? _____ gallons

How does this figure compare with the water savings computed by other students in your class?

What seems to be a reasonable number of gallons that could be conserved by all people you know? This will be determined by discussing average water uses in homes in your immediate area (for example, other members of your class).

How much water could probably be saved per person per week in your community? _____ gallons

At this point you are to find out the population of your community. Multiply the newest average number of gallons saved by the population of your community. This will give you an estimate of the amount of water that could be conserved in your community alone.

Estimate the amount of water that could be conserved each week in your community. _____ gallons

Next, compute the number of gallons that could be conserved in the community each year. Simply multiply your last figure by 52.

Estimate the amount of water that could be conserved each year in your community. _____ gallons

Would this estimate of the water that could potentially be saved have an impact on water resources in your area or community? Would it conserve the underground water supply? Might it help solve a critical water shortage? Would it mean less stress being placed on the municipal water works? On the sewage disposal system? You might call the water company and the sewage disposal facility and inquire about these last two questions.

How would your estimate of water consumption savings in the home look on a national basis? It is a relatively simple matter to compute this. There are approximately 225,000,000 people in the U. S. today. However, remember, if there is an error in your original estimate, you will be multiplying that error by 225,000,000!

PART XII

Science In Special Situations: Children With Special Needs

Performance Objectives

Subsequent to your interactions with Part XII, you will be expected to be able to. . .

1. . . . explain why the classic criteria of I.Q. and reading ability are ineffective for identifying many gifted children. You will be expected to specifically note "gifted attributes" not generally isolated by traditional I.Q. and reading test instruments.

2. . . . briefly explain how science instruction can provide success for a wide range of student ability levels in the elementary school.

3. . . . specifically cite several attributes of a teacher who can provide success for a wide spectrum of students including slow, gifted and handicapped using science as a vehicle.

4. . . . take any one major concept that has general education value for children (e.g., sexual reproduction, interaction, energy transfer, the ecosystem) and demonstrate an ability to communicate how that concept can be inductively generated at various ability levels.

5. . . . explain why the disadvantaged child's educational values may prove to be the most educationally debilitating attribute reflected by that student.

6. . . . analyze and react orally or in writing to the following true episode: "A few years ago, the senior author of your worktext was principal of a 1000 student junior high school in the midwest. One of the students was a black girl who manifested a set of values inconsistent with the values of the school and its educational program. Many problems for the girl - and the school - resulted. The writer, along with the girl's counselor, decided to visit the home and attempt to communicate with the girl's mother (the father was not in the home) the school's need for parental cooperation. After arriving at the girl's home, the two educators were met by the girl's mother and her older sister, a reputed prostitute. A friendly but forceful effort was made to help the mother and the girl's sister perceive the need for value modification on the part of the junior high student. The mother was noncommital and the girl's sister laughed out loud. No value modification resulted!"

In your analysis, logically hypothesize as to why the school's principal failed in his mission. Also, attempt to suggest a strategy that might have been more successful in modifying the girl's values.

7. . . . list and defend the choice of at least four (4) different strategies that could be used to broaden a child's experiential background in science.

8. . . . explain why the technique of using the disadvantaged child's own environment to facilitate educational achievement could be detrimental to the child if carried too far.

9. . . . choose any one category of children with special needs, identify the specific needs of those children, and design a science teaching strategy (in the form of a teaching unit) which helps meet those needs. You must be able to defend the educational assumptions which are reflected in the unit.

Science In Special Situations: Children With Special Needs

> Through proper adaptation of the elementary science curriculum to the needs of this large portion of our children, we may bring about an enrichment of their lives which, in turn, will benefit our entire community. We have, so far, failed to tap America's greatest resources, the creative skills and abilities of all its children. Among these disadvantaged children, there is a large reservoir of future high-level, professional, and skilled personnel, if we learn how to help them realize this potential.
>
> Samuel Malkin - 1964

It seems a shame to have to categorize children as "slow" or "learning disabled" or "disadvantaged", or "gifted", or this . . . or that! Such labels have a tendency, oftentimes, to operate in a detrimental fashion for both teachers and students. Far too often teachers are prejudiced against "special populations" of children and, far too often, children perceive how they have been categorized and function accordingly, irrespective of how they could function from a socio-educational standpoint.

The writers must assume, simply from a time and energy standpoint, that these detrimental conditions do not operate in classrooms - knowing full well that this is not the case. For pragmatic reasons we will assume that there are not bigoted teachers and that education's labels do not manifest themselves in detrimental and self-debilitating behavior.

This section supposedly deals with the topic of "science for children with special needs". In so doing, the writers are compelled to deal with other educational components as well, since science education as such does not and cannot operate in a sociocultural vacuum. Science offers tremendous opportunities for many children with special attributes but, by itself, it can provide no miracles and no panaceas!

Science for "Slow" and "Gifted" Children

If the reader is aghast at seeing both "slow" and "gifted" subsumed under the same heading it would not be too surprising. This would be the case, particularly if the classic criteria were used in identifying these children, i.e., they are sorted out and labeled according to reading ability and I.Q. Even though these two criteria are useful in certain diagnostic situations, they often end up being the sole conditions under which labels are applied. If this be the case, what happens to the child who cannot read for psychological reasons and, therefore, functions poorly on the mental ability instrument? What happens to the child who has "better than average" cognitive potential (in any one of a number of areas) but, because of a weak cultural background, cannot cope successfully with those I.Q. test items that demand a cultural literacy? Is this child expected to perform at a high cognitive level? Will the child perform at a high cognitive level? Remember, there is research evidence to support the notion that children tend to perform in ways we expect them to perform. Needless to say, this generalization is not an educational absolute; it is simply a general predictor of performance. Even so, it bears tremendous implications for the classroom teacher.

Fortunately, educators are beginning to sense that reading per se and I.Q. performance per se are only two attributes of the human organism. We perceive the importance of musical aptitude, manual dexterity, problem solving, creativity, and leadership, for examples, as important human conditions and ones that can be fostered successfully in classrooms. It is possible for the culturally disadvantaged child to be talented . . . gifted, if you will. Yes, and it is also possible for these same children to be talented in areas in which, traditionally, we would not expect them to be talented, e.g., problem solving. These statements are far more than platitudes - they are realities! However, they demand teachers who are willing to avoid the common pitfalls of instruction. These teachers ignore debilitating labels. They apply positive reinforcement and do everything possible to develop a more positive self-image on the part of the child. They circumvent the classic barrier to academic success - the inability to function effectively in reading. They attempt to communicate with the home and provide support there similar to that given at school.

The senior author recalls a seventh grade student under his jurisdiction who was termed "slow" and a "poor achiever". This seventh grader attended to these labels with care and expertise as he failed in math, social studies, and language arts. His same affective behaviors were destined to be tried in science class as well. The labels which were given to him by his teachers were accepted casually by him and his peers. Further, these labels were also accepted by some of his teachers with considerable concern . . . even hostility. He was, in fact, quite capable of sending a select group of his teachers "up the classroom wall" at will. Still, the student had some characteristics that bent the patient teacher toward him. His smile at times was a winning smile and his sense of humor, although often misdirected, was keenly tuned. To attempt to proclaim that his science teacher had zero problems would be to falsify the issue but science eventually proved to be the vehicle that ruined his academic record of failure or near failure.

The key for this student proved to be a problem solving strategy that directed the students to interact with the teacher in a manner that provided the students with data leading toward closure with specific hypotheses. This strategy demanded a good deal of divergent thinking on the parts of the students

prior to closure. This approach intrigued this young man because he could think for himself and was not being forced to read and regurgitate factual information. It became evident that his ability to synthesize information was extraordinary. Since the students were evaluated in a manner consistent with the training, this young man earned an A in science. Remember, he was labeled "slow" and a "poor achiever". And yet, his cognitive problem solving ability was superb!

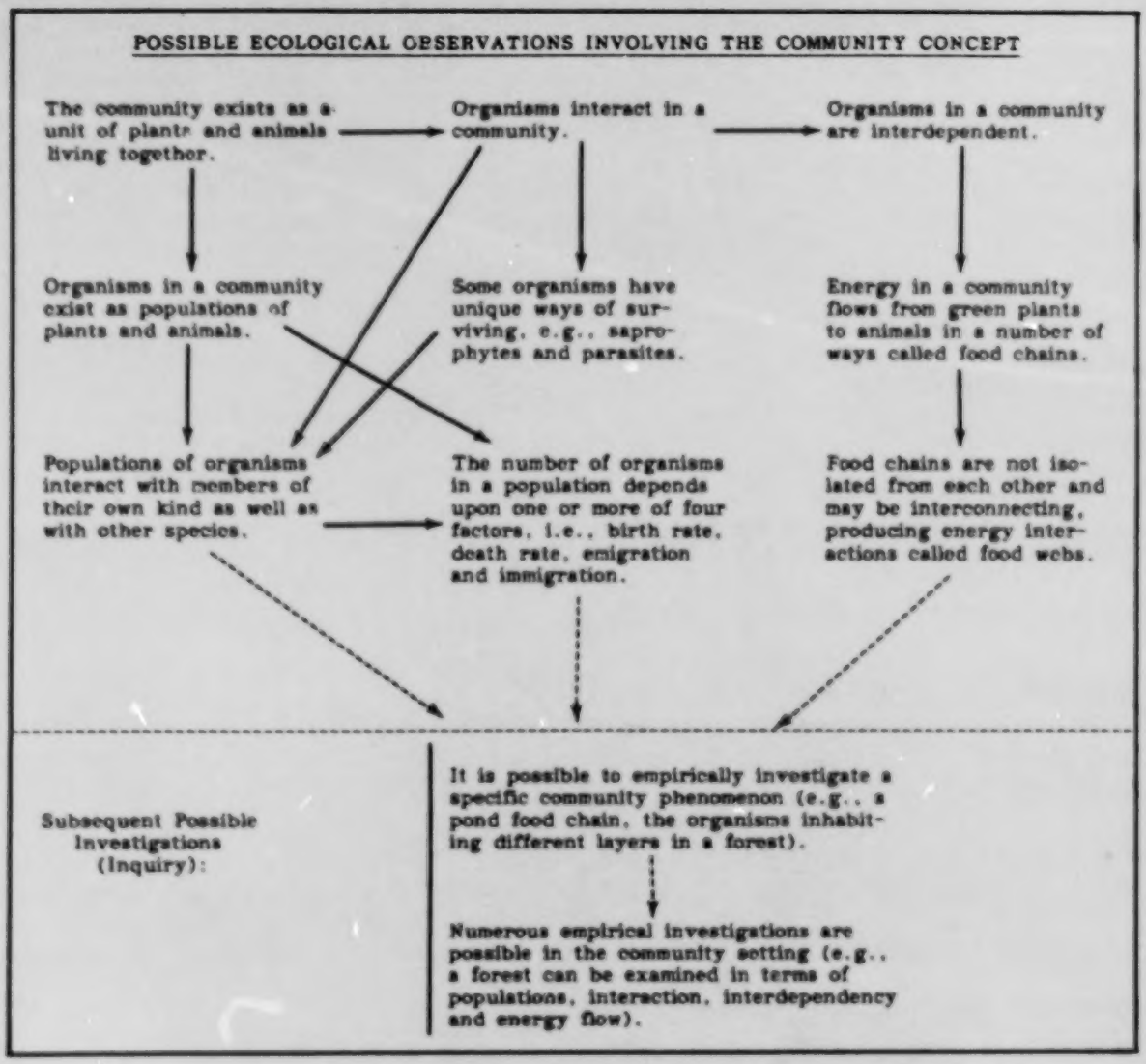
How many students like this one fail consistently and remain "slow" or "failing" in classrooms across the nation? The number, unfortunately, must be staggering and the prognosis for these young people is discouraging at best unless we as educators meet their needs. You will undoubtedly have that opportunity!

How Science Can Provide Success For A Broad Range of Abilities!

The very nature of science is beautifully structured to meeting the academic and many of the general education needs of a wide array of intellectual types. Surprisingly, there are few hard and fast, right or wrong answers in science. Science, as you already know, is simply man's way of empirically investigating his universe. This surely denotes a continuum along which knowledge can be collected, i.e., empirical evidence can range from minimal to exhaustive. Given any particular inquiry in the classroom, therefore, children should be able to be successful in dealing with it even though not all will function at the same level or with the same expertise. Superficially, this may seem of only marginal significance. But, when compared with the traditional format of "right" or "wrong", the implications for academic success are staggering. Imagine an instructional format which permits the teacher to positively reward all children. This is precisely the potential of science - if taught as science and not simply as a supplementary reading program. The same conditions, of course, should exist in other curricular areas as well!

Let us use one example at this point to demonstrate this principle. If in the intermediate grades, the teacher determines to focus on the "community concept" in ecology, numerous inductive strategies are available. These range from classroom investigations into microcommunities (e.g., those used in the Science Curriculum Improvement Study) to investigations into locally available macrocommunities (e.g., ponds and forests) or combinations of these strategies or others. Assuming that the teacher uses an inductive stragegy which permits students to make their own observations and draw their own conclusions, we can project a complex array of subconcepts being generated from the investigations. One student might have the ability to conceptualize the community at a very rudimentary level, e.g., the living community is composed of plants and animals. Another may have the cognitive ability and motivation to generate a much more complex concept (or set of concepts, e.g., plants and animals in a living community interact and are interdependent). Further, some students may bring forth new inquiry possibilities, providing themselves with ways of extending their knowledge of the "community".

The diagram on the following page illustrates a few of the concept and inquiry possibilities available from investigation of a natural community. Getting back to the original point, this helps demonstrate how science inquiry develops


POSSIBLE ECOLOGICAL OBSERVATIONS INVOLVING THE COMMUNITY CONCEPT
The community exists as a unit of plants and animals living together.
Organisms interact in a community.
Organisms in a community are interdependent.
Organisms in a community exist as populations of plants and animals.
Some organisms have unique ways of surviving, e.g., saprophytes and parasites.
Energy in a community flows from green plants to animals in a number of ways called food chains.
Populations of organisms interact with members of their own kind as well as with other species.
The number of organisms in a population depends upon one or more of four factors, i.e., birth rate, death rate, emigration and immigration.
Food chains are not isolated from each other and may be interconnecting, producing energy interactions called food webs.
Subsequent Possible Investigations (Inquiry):
It is possible to empirically investigate a specific community phenomenon (e.g., a pond food chain, the organisms inhabiting different layers in a forest).
Numerous empirical investigations are possible in the community setting (e.g., a forest can be examined in terms of populations, interaction, interdependency and energy flow).

knowledge along a wide continuum and, therefore, has the potential for providing for a wide range of student abilities - from "slow" to "gifted".

Of course, one runs the risk of finding that teacher who demands all or nothing from his/her students. The "continuum strategy" would not work for a student under this teacher's leadership. This teacher, of course, manifests an inability to perceive the nature of man's cultural heritage and, in addition, fails to understand his/her responsibilities in a general education context. It is that same teacher who myopically expects all children to reach one level of human achievement and fails those who cannot. It is this same teacher who generally focuses on only a few facets of the human intellect in her classroom, generally the acquisition of factual information evaluated by true and false or poorly-constructed multiple-choice tests. You, of course, can identify this teacher with little effort because he/she is the one who suffers from the "Johnny Can't Do

That Teachers' Lounge Syndrome". With better pre- and inservice training, teachers with these characteristics are slowly disappearing from the American classroom. Unfortunately, no magic wand exists to instantaneously remove all such instruction from schools across the nation.

Hopefully, as you have been reading and thinking through this section, you have generated some logical thoughts about the kinds of activities appropriate for these kinds of students. Possibly, however, you have been waiting to be told of some appropriate strategies.

Earlier, you were given specific introduction to three of the major science programs in the United States, i.e., SAPA, ESS, and SCIS. Even though these programs differ markedly, each can be recommended for the purposes discussed in this section. Each is investigative in nature. Each permits at least some latitude in acceptable student progress. Each can be extended in terms of learning activities that go beyond the basic content provided by the program. None of the programs demands a great deal of reading skill in order for a child to succeed. Each program is based on the doing of science - a key characteristic for children who have hidden talents and a natural eagerness for investigating their environment. Further, each has been proven sound for a wide range of ability levels. In fact, one program, SCIS has been adapted for visually impaired students.

The teacher, however, need not use a major science program to provide for individual differences in the science area. The reader is directed to Part XIII of this worktext where attributes of an effective science program are listed. Any teacher who consistently plans for science instruction and follows these principles will be providing for a wide range of student ability.

Science For Disadvantaged Populations

"Disadvantaged" is a relative term. Further, it should be used cautiously. It is, after all, another label and we have already discussed the debilitating effects of labels - both on teachers and students. Why, then use it here?

The writers choose to use the adjective simply to put the educational needs of differing populations in perspective and make suggestions in terms of using science as an effective tool in making greater numbers of human beings more effective members of society.

Perhaps the only generalization that is an absolute with reference to disadvantaged populations is that it is frighteningly difficult to generalize! There is no such thing as a typically disadvantaged human being, regardless of how many modifiers we use. One group of human beings may be culturally or educationally disadvantaged from one standpoint only to find another population disadvantaged from another. The poverty-stricken, urban ghetto black child is not the same individual as the midcontinent poverty-stricken and isolated white child. Neither of these conforms to the general description of the Mexican-American child caught up in the mores and cultural configurations of the migrant worker. And the impoverished Navajo child is different from all others. On and on. . .

Differing cultural patterns produce differing needs. Differing needs demand differing educational strategies and woe unto the teacher who finds representatives of two or more culturally deprived populations in the classroom. Indeed, the frustrations encountered in such a situation can be horrendous for the ethical teacher. Many teachers thusly challenged have seen fit to move or drop out of the education scene completely.

Still, we must begin somewhere and establish a premise for attacking the problem. What are the characteristics you might encounter in a given disadvantaged population of children?

Some Characteristics Of The Disadvantaged Worthy of Note

First, a culturally disadvantaged child is one who is kept, for one reason or another, from a wide variety of experiences which reflect the structure of the dominant culture. The child may be successful in the subculture in which he exists but almost totally incompetent to deal with those variables that permit success in standard educational programs and, subsequently, in the socio-economic cultural establishment in which he can find maximal fulfillment as a human being. Educational success is dependent, to a large extent, on the experiential backgrounds of the human beings involved and the disadvantaged child comes to a formal education quite often with a barren background, not knowing, for example, that the English language is read from left to right and top to bottom.

A given disadvantaged population may also possess a system of values completely inconsistent with educational success. In fact, if there is one single detriment to success for many disadvantaged populations, this is it! The child perceives that his family cares not whether he succeeds in school. Further, and even worse, he routinely overhears the four-letter criticisms leveled at teachers and schools. It becomes, then, not a matter of passive participation but one of overt aggression directed at any educational institution or human associated with that institution. Turning this situation around is excruciatingly difficult and this is one condition that must be countered if the disadvantaged child is to be culturally emancipated.

Self-image is still another criterion that creates educational problems. Consider the six or seven year old who perceives himself, to put it mildly, at less than standard and what do you have? You have a young human being who fails to believe in himself and, therefore, who is prone to failure. It is that simple!

And what of poverty? Can we generalize and state that economic deprivation is also one ingredient of cultural deprivation? Not necessarily! It is possible to be poor and culturally adjusted. It is possible to be wealthy and culturally maladjusted. Typically, however, there is a correlation between poverty and being culturally disadvantaged. Since the reasons appear obvious we won't go into them. But, to overgeneralize here is to put labels on many children who don't deserve them - a tragedy that must be avoided if at all possible.

Can culturally disadvantaged children be perceived as individuals? Or can this very category permit us to treat them all alike - for their own good? Even though the latter is sometimes done out of combinations of prejudice,

sympathy, ignorance, fear, and misplaced benevolence, such must not be done. All children are individuals and all must be treated as individuals.

One of the very real dangers of labels is the stereotypes that follow the labels. All disadvantaged children, apart from being individuals, are disadvantaged by degrees. In fact, probably all human beings are disadvantaged to some degrees. Further, where we turn the corner from "Culturally Disadvantaged Avenue" onto "Culturally Advantaged Avenue" is questionable. Generally, however, we would consider any child who lacks those values and experiential background that can afford success in school to be disadvantaged. Be that as it may, given ten disadvantaged children, you probably have ten different degrees of disadvantagedness.

What Can We Do For The Disadvantaged?

We begin on a note of pessimism. The writer's own educational background working with ghettoized blacks and urban disadvantaged whites as well as rurally disadvantaged children, demands a straightforward cautionary note. For those young people who come to the educational experiences with a set of values not commensurate with the values espoused by basic educational institutions (i.e., that education is a productive and worthwhile endeavor), some strategy must be embraced that can modify those debilitating values. If the inappropriate values cannot be changed, any other efforts to improve the students' education experience will be largely worthless. As tragic as it appears, this tends to be reality. Further, if the debilitating values are reinforced over and over again at home, efforts to change those values via a school-centered experience are fraught with failure. Can nothing be done? On the contrary, a great deal can be done but only where a method exists to help modify values communicated by the home.

What strategies work? None work completely. However, if the school or its agents can help the parent(s) perceive the value that an education can have for the child, the values communicated to the child in the home can change and the child's attitude toward school effectively modified. Some schools have a visiting counselor program to facilitate change. Some schools rely on the teacher to go into the home and help establish a positive relationship. A variety of strategies can be employed. However, the attempt must be made!

With respect to the child's self-image, the teacher can do a great deal. One effective strategy is to employ a cycle of success for the child - to structure the educational world so as to permit the child to enjoy and experience success over time. Once a decent positive self-image begins to appear, a belief in "self" contributes to academic effort and achievement. As noted in a prior paragraph, science offers great potential here because it can lead to success at various levels of cognitive performance.

The easiest problem with which to deal (and one where many schools fail miserably) is that related to the child's experiential background. The disadvantaged child needs an expanded experiential base from which he can operate intellectually. Further, these experiences should be acquired in contact with the real, three-dimensional world of the child. One of the major failures of the elementary school is its seeming psychosis for keeping children within the confines of the two book covers and four classroom walls. This basic absurdity

Children and teacher grinding cranberries for relish.

Photograph by A. N. Tomera.

disregards almost completely the realities of the environment in which the disadvantaged child exists and assumes that a totally surrogate world can meet the educational and social needs of such a child.

Answers are not absolute but many suggestions can be given which effectively deal with the child's experiential awareness. First, and foremost, experiences should be concrete, particularly for young children. An opportunity to manipulate the three-dimensional world is crucial for effective conceptualization. The closer the experience is to reality, the better the intellectual pegs on which the child can hang his memory. Instead of reading about how bicycles produce a mechanical advantage, why not bring one into the classroom and study gear ratios in reality? And yet, how often is this done? Instead of reading about and seeing pictures of trees and their ecological roles, why not have each child choose a tree or shrub in the area and observe it on a select schedule so that a log or diary of observations can be maintained? And, yet, it is doubtful that many teachers of disadvantaged children use the "Tree Diary" as a means of

extending knowledge. Instead of talking about seasonal change, why not take a field trip to observe change - to measure the length of shadows as they change over time - and observe the relationship that exists between the position of sun and seasons?

The writers believe, also, that a regular, experiential science program can effectively promote science and, therefore, cultural awareness. However, for the disadvantaged child this is probably not enough. You may question this position because you know how much time must be spent on the basic skills. Is there really no time for science? Or the social studies? Does so much time have to be spent on the 3 R's? But, the 3 R's are of little worth to the disadvantaged child when treated out of the context of reality. This is one reason why many efforts for providing for culturally disadvantaged children have failed. Some teachers unfortunately perceive skills as an end in themselves and the content leading to those skills to be insignificant. In actuality, the reverse is the appropriate perception! Use content that turns the child on! Use content that the child needs! Use those content selections as vehicles to get at skills! This works surprisingly well.

It then becomes a problem of providing more science experiences (or environmental experiences if you prefer) for the disadvantaged child than for the "advantaged" youngster. When the content portion of the curriculum provides for both conceptual awareness and for vehicles to get at basic skills, this problem becomes negligible. This pattern provides the time needed.

One of the major thrusts of education for the disadvantaged child has been to deal with the child's own environment, i.e., use the child's own setting as a focus for educational experiences. If in an urban setting and studying insects, one would deal with cockroaches, flies, lice, and bed bugs of the ghetto. If studying mammals, he would deal with feral dogs and cats, gerbils, rats, and other human beings. If studying food chains, he would explore the food chains in which sparrows, chimney swifts, cockroaches, rats, lice and bed bugs were involved. This strategy has its merits because the child has already established referents to many of these objects. It is entirely true that familiarity breeds success. However, the educational program dare not end there.

Eventually, the disadvantaged child must be taken out of his immediate environment. The rationale is so simple that it boggles the mind to see educators who fail to perceive it. If we do not expand the cultural horizons of the disadvantaged, we simply provide a condition that guarantees that the child cannot escape his subcultural destiny. To do so is educationally unethical. Many are the urban children who have absolutely no concept of "country". Many are the rural children who have little concept of "city" or "subway". Both populations may never have been to a zoo or a planetarium much less a seashore or a museum.

The implications are clear. These children must be taken out of the classroom and exposed to segments of their universe with which they have had no contact and with which they need contact. And yet, the writers have met potentially competent teachers who refuse to leave the classroom even when they have the opportunity. Similarly, there are teachers who would love to use the real, three-dimensional world to expand cultural horizons only to be refused that opportunity by their administrators and/or school boards. In either situation, it is critical to change the conditions - for children who desperately need expanded horizons.

And What About The Handicapped Child?

Although the school has always had to be concerned with handicapped children, recent federal legislation has made this concern a legal responsibility. In 1975, the United States Congress passed The Education For All Handicapped Children Act (Public Law 94-142) which requires that all children and youth be provided a free and appropriate education. Appropriate education has come to mean that a student must be placed in a regular school environment if the student can function in a regular classroom with a regular teacher. Although this does not mean that all handicapped children will be placed in regular classrooms, it does mean that many will be. Regular classroom teachers must now deal with "mainstreamed" handicapped students who may suffer from any or a combination of the following categories of impairments: mental, hearing, visual, speech or language, physical, behavioral, or educational. Along with many of these impairments come problems such as poor attention spans, language skills, poor self image, poor self-control, and poor peer interaction skills.

Teacher-training institutions have responded to PL 94-142 by providing required coursework which assists the regular classroom teacher in dealing with "mainstreamed" handicapped children and in understanding the teacher's responsibilities as mandated by the law. Therefore, our purpose in this section is to suggest some specific teaching techniques for teaching science to handicapped children. Interestingly, the techniques for teaching science covered in the entire worktext as well as many of the specific suggestions made in this section also apply to handicapped students. For example, the use of experiental science rather than a "read about it" program is essential for many handicapped students. They, too, must be given an opportunity to succeed and that opportunity must not be predicated on reading ability. Further, the teacher must view these students in terms of their potential rather than their liabilities. Content must be selected which is attainable at these intellectual and/or physical levels. Their experiential backgrounds must be broadened. Activities must be paced for their intellectual processing levels. Positive self-image must be developed. And, student success with activities that will encourage that development rests in the hands of the informed teacher. There also exist special materials for the teacher of science to use with handicapped students. A sampling of these materials with annotations and their sources are listed below:

1. Ball, Daniel W. ESS Special Education Teachers Guide. New York: Webster Division, McGraw Hill Book Company, 1978.

2. De Lucchi, Linda et al. "Science Activities for the Visually Impaired: Developing a Model." Exceptional Children 46(4): 267-288, Jan., 1980.
   Describes the Science Activities for the Visually Impaired (SAVI) program developed for use with blind and visually impaired children, aged 9-12.

3. Francoeur, Pearl and Eilam Bihah. "Teaching the Mammalian Heart to the Visually Handicapped - A Lesson in Concrete Experience". The Science Teacher 42(10): 8-11, Dec., 1975.
   Programmed instruction is used with concrete experiences and raised diagrams to teach the mammalian heart to both sighted and visually handicapped students.

4. Hoffman, Helenmarie and Recker, Kenneth. Sourcebook: Science Education and the Physically Handicapped. Washington, D. C.: National Science Teachers Association, 1979.
This sourcebook is a compendium of articles and printed papers regarding all types of handicapped students in relation to science teaching techniques.

5. Jones, Alan and Barnett, Anthony. "Science for the Physically Handicapped". Special Education: Forward Trends 7(3): 25-28, Sept., 1980.
Several experiments designed to provide safe science activities for junior high school physically handicapped students are described.

6. Kaschner, Susan. "Viewing the Earth With Closed Eyes." Science Activities 15(3): 12-13, 1978.
Describes earth science activities for the visually impaired student.

7. Post, Thomas R. et al. "Laboratory-Based Mathematics and Science for the Handicapped Child". Science and Children 13(6): 41-43, Mar., 1976.
Suggestions are given for planning a laboratory - based program, and guidelines for teachers of both handicapped and non-handicapped students are included. NOTE: The entire issue of Science and Children (13) is dedicated to the definition of handicapped students as well as science programs and activities for these individuals.

8. Vannan, Donald A. "Science Activities and the Retarded Child". Science Activities Dec./Jan., 1974, 37-38.
Ten resource articles and books useful to elementary teachers who wish to provide science activities to slow learners and retarded students are briefly discussed.

9. Their, Herbert and Hadary, Doris. "We Can Do It Too". Science and Children 11(4): 7-9, Dec., 1973.
Describes some adaptations of science exercises found in the program, "Adapting Science Materials for the Blind".

10. Their, Madeline. "Utilizing Science Experiences for Developing Visual Perception Skills". Science and Children 13(6): 39-40, Mar., 1976.
Alternative approaches for developing visual perception skills using selected science experiences are described.

11. The entire issue of Science and Childen 16(6): March, 1979.
Contains 17 articles on science and the gifted.

12. Biological Science Curriculum Study. Me Now. Northbrook, IL: Hubbard Scientific Company, 1973.
This upper elementary program is a life science approach for use with educably mentally handicapped students.

In Summary It can be debilitating to put labels on children in classrooms even though categorization is sometimes necessary before remediation can take place. To identify children as "slow" or "gifted" on the basis of I.Q. and reading ability is to refuse to

accept many of the talents and potential talents of children. Science, because of its openended nature, is adaptable to a wide assortment of children with differing needs and abilities. Science instruction can provide a vehicle whereby all children can enjoy success - the slow, the gifted, the culturally disadvantaged and the handicapped.

Numerous cultural variables impede scholastic success for the "disadvantaged" student. Students' values and self-images must be commensurate with educational values and a belief in one's self before major achievement can occur. A broad experiential background is essential for educational success. If appropriate steps are taken a child's experiential background can be strengthened substantially by the school. Science provides an excellent vehicle for broadening experiential backgrounds and providing for training in basic skills in other content areas. Although it is essential to use the disadvantaged child's environmental frame of reference as an educational tool, his cultural referents must also be increased in order to provide for an expanding foundation for personal success.

Food For Thought

> There may be other things which schools could or should do, but they could or should do these things only after they have, . . ., patiently and persistently as they can, taught the use of that unique instrument of their humanity, the restless, questing mind. . . . Whenever a boy or girl in this country receives a less challenging, less appropriate, less worthy education than he or she mentally and morally deserves, there is a diminishing of the person, an impoverishing of a life, possibly a great loss to the nation, and a defeat suffered in the sector of the engagement of the mind of man with the mystery and wonder of the universe.
>
> William H. Cornog - 1963

PART XIII

A Comparison of Traditional and Modern Science Methods

TRADITIONAL SCIENCE METHODS

STUDENTS:

- READ AND MEMORIZE
  - information about science
- AND DO
  - cookbook lab exercises
- WHICH REFLECT
  - little motivation
- IN ORDER TO
  - please the teacher
  - gain a good grade
- WHICH RESULTS IN
  - poor retention
  - little transfer
  - fewer cognitive skills
  - failure for many
- AND DEVELOP THE ATTITUDE THAT
  - science is boring
- AND EXPERIENCE
  - a poor educational technology.

MODERN SCIENCE METHODS

STUDENTS:

- PARTICIPATE IN
  - the science enterprise
- WITH
  - high motivation
- BECAUSE THEY ARE
  - doing science
- WHICH RESULTS IN
  - inductive learning
  - critical thinking skills (processes)
  - long term retention
  - transfer potential
  - success for many
- AND DEVELOP THE ATTITUDE THAT
  - SCIENCE is important and interesting
  - school can be an exciting place to be
- AND EXPERIENCE
  - an improving educational technology.

Conditions Necessary for an Effective Elementary School Science Program

1. The science program should be considered as an integral part of the general education of all children in that it focuses on the development of scientifically literate human beings.

2. Adequate time should be provided for the science program; no less than 150 minutes per week should be scheduled for science for all grade levels. Further, teachers should recognize the value of science as a content vehicle in a number of other curricular areas and wisely use it for that purpose.

3. The science program should continually be evaluated in terms of whether it is meeting its goals and, in particular, the general education needs of children.

4. The science program should teach both cognitive skills (science process) and important conceptual knowledge. Further, these same skills and concepts must be taught in such a way as to permit their transfer to new and unique situations of importance to the students.

5. The science program should be experientially oriented whenever possible. Students must have an opportunity to DO SCIENCE.

6. The science program should develop in each child a concept of what science is and what kind of a human being a scientist is.

7. The science program should provide for a wide distribution of student abilities, i.e., all students should be successful in meeting instructional objectives in science.

8. The science program should reflect specific instructional objectives (in behavioral terms) and these objectives should be communicated to the students and used for evaluation.

9. The science program should provide students with a set of attitudes toward their natural world and toward science commensurate with their personal needs and the needs of the society in which they live.

   A. The science program should provide a concept of the tremendous implications science has had on society as well as a correct concept which alludes to the very real limitations of science as they pertain to solving many of man's personal and social problems.

   B. The science program should help the child understand that he is inexorably tied to his environment and that his survival and the survival of subsequent generations depends upon man's management of that same environment.

10. The science program should incorporate not only the intellectual facets of pure science but also the domain of technology in order that every student can differentiate between science and technology and also understand the relationship that exists between them.

> . . . demand that every citizen have a basic and functional understanding of the products of science - the concepts, the principles and the facts; and be able to understand and use the process of science - the modes of thought, the attitudes of mind, the tactics and strategy, and the appreciations. . . . . This goal can be achieved through the schools in every hamlet and city across the Nation. It can be realized, however, only as it is initiated by local effort and grows up from the grass roots. It must have the support of every citizen in every local community. It will require a concerted and organized effort, but these costs are low when weighed against the realization that this kind of education in science may be basic to our survival.
>
> Ellsworth S. Osbourn - 1961

APPENDICES

APPENDIX A

More On Concepts -- An Assignment

As you now know, conceptual knowledge is the basis for what we know and, further, provides an intellectual foundation which permits us to mediate new information. To a marked degree, conceptual knowledge also assists us in the use of the skills of critical thinking, i.e., the scientific processes.

Every intellectual discipline of man (e.g., history, sociology, biology, chemistry and earth science) has a certain conceptual or cognitive structure. It is this structure that permits the domain of that discipline to be integrated and made available to us intellectually. The bulk of the structure of the knowledge of any discipline is conceptual in nature. Permit us an example of a small compartment of the structure of the conceptual knowledge in one intellectual discipline, earth science.

All of us know that the landscape features on the earth's surface make up the physiography of this planet. Let us start there and further clarify the "why" of physiography using a set of closely-related concepts.

> Concept 1. Both naturally occurring constructive and destructive forces influence the development of landscape features on the earth's surface.
>
> Concept 2. Naturally occurring constructive forces include volcanism and diastrophism, i.e., the bending or breaking of rocks in the earth's crust.
>
> Concept 3. Naturally occurring destructive forces include those factors involved in the weathering or breaking up of rocks (e.g., solution, frost wedging, exfoliation) plus those factors involved in the erosion or transportation of rock debris (e.g., gravity, wind, water).

Now we could go on from this point and further develop each major concept stated above but that shouldn't be necessary. You should see the relationships existing between these concepts and perceive why a person's understanding of these would be dependent upon his background of experiences with the objects and phenomena described by those conceptual statements.

Now, there appear to be a couple of things that are important here for teachers of children. First, before teachers can effectively provide meaningful learning experiences for students they must have some understanding of the structure of the knowledge with which they are dealing; second, teachers who have the option of deciding what is to be taught should make decisions based on the importance of the information to the child, i.e., what is truly important from a general education point of view. This correctly infers that we must be able to defend what we teach.

If one were to teach the three concepts dealing with the changing earth's surface, he/she might logically use the following defense for his/her position.

> Rationale: Man is an inhabitant of the planet Earth and as of this moment in time, is bound to the planet and dependent on it for his very survival. The interactions between man and his environment are numerous and include those that take place with the earth's crust.
>
> Although many of the forces of crustal construction and destruction are subtle in nature, several are dynamic and dramatic, i.e., volcanoes, earthquakes, landslides. An understanding of the nature of crustal movement and change should help facilitate a human's adjustment to his environment. This would, of course, include freedom from fear and superstitutions.
>
> Further, the factors of weathering and erosion are of critical importance to man's personal welfare in that weathering substantially contributes to soil formation and the forces of erosion can wreak havoc with man's agricultural lands. Similarly, exercising control over the environment (with respect to weathering and erosion) demands that man first understand the phenomena he is attempting to control. It would appear, then, that the culturally applicable aspects of these concepts hold considerable promise for improving man's relationship with the universe in which he lives.

The Assignment - Because your professors perceive the logical decision-making related to the solution of science content to be crucial to a fundamentally sound science program they are going to give you an cpportunity to get involved in this endeavor.

This involvement will include the judicial selection of conceptual knowledge and a reasonable and logical defense for that selection. You are to prepare a two page paper following the task descriptions below:

Task One: Choose a portion of a science discipline. Select and state a set of related conceptual statements which you perceive to be of critical importance to human beings, in this case, elementary school students. This concept set should consist of no fewer than two and no more than four.

Task Two: You have chosen the related concepts! Now, tell us what gives you the right to take up the child's time and energy in the development or acquisition of these concepts. Why are these concepts important - or crucial - to a human being's general education? State a logical and meaningful rationale using no more than 200 words. Be as succinct as possible!

APPENDIX B

Supplementary Reading Assignment

This assignment is designed to broaden your background in a facet of elementary school science education which is of particular concern or interest to YOU. The number of readings required in this assignment plus continued reading (done on your own) will help keep you abreast of current thinking in the field. The assignment is meant to be an opportunity to give you an indepth view of the topic you choose.

INSTRUCTIONS:

1. You will choose a topic in elementary science education, either from the suggested list found below or one of your own interest (which requires the agreement of your instructor). Samples of topics are: 1) discovery learning in science; 2) process instruction; 3) question-asking strategies; 4) the unit approach to science education; 5) science career awareness; 6) instruction in science-related social issues; 7) science for the gifted child; 8) developing scientific attitudes; 9) motivation in science; 10) using community resources in science; 11) integrating science with other subjects; 12) use of field trips (or outdoor education) to teach science; 13) environmental education; 14) concept development in science; 15) the textbook and its place in science education; 16) teaching science experientially; 17) using science in special education; 18) teaching science to the young child; 19) use of microcomputers in science teaching; 20) evaluation of science learning.

2. You will then read at least SIX (6) journal articles on your chosen topic. Please select a topic on which you can find sufficient, current journal coverage (1975 to present). SUGGESTED JOURNALS ARE:

Science and Children	School Science and Mathematics
The Science Teacher	Science Education
The American Biology Teacher	Journal of Research in Science

Also use the Reader's Guide and the Education Index. Pertinent articles often appear in such journals as Illinois Education; the NEA Journal; Today's Education; Learning; the Kappan and others. Please be sure that the articles you choose directly relate to your topic.

3. After reading these articles you will prepare a 1000 word paper (maximum) which is to be a brief summary of the topic on which you have become knowledgeable. This is not to be a discussion of the six separate articles. Use the ideas gleaned from your articles in your discussion of the topic. You should also evaluate the information read in the articles as part of the paper's coverage.

4. The end-product (paper) is to be a typewritten, concise, coherent, smooth-flowing synopsis (summary) of the topic you selected. The paper will include:

   a. a title page designating your topic and identifying your authorship.

   b. the paper itself (watch your word limits--1000!) NOTE: one double-spaced typewritten page constitutes 250 words.

c. citations within the paper (incorporated into your synopsis) of some of the bibliographical references you used. A good way is to use the name of the author of the article if you paraphrase or quote from your references. PLEASE DO NOT USE FOOTNOTES. A sample citation form is: Smith (1979) stated that science is important for general education purposes.

d. a final paragraph containing YOUR HONEST EVALUATION of the ideas you have presented in this paper. Platitudes and glittering generalities are not appreciated. You might want to evaluate the usefulness of methods for valuable science learning, for example.

e. a bibliography (on a separate sheet of paper) of the articles you used (READ) to gather information for your topic. Your bibliography must include AT LEAST TWO DIFFERENT journals within the six you have listed. The bibliography is to be done in a standard, correct style. One such example is presented below:

Williams, David L. "On Science for Young Children". Science and Children 13:34-35; October 1975.

5. DUE DATE: As announced by your instructor.

6. GRADING: Your grade will be based on the degree to which your paper has met the guidelines of this assignment. The following criteria will be used:

a. organization and discussion of the topic

b. cited used of references in the paper

c. bibliography (relevancy of articles, diversity of journals, correct form)

d. summary - your evaluation of the topic covered (quality and depth of perception)

e. grammar, spelling, neatness.

APPENDIX C

Writing and Analyzing Performance Objectives

Appendix C has been prepared to provide practice in analyzing and writing performance objectives. The activities herein should contribute substantially to your understanding of and ability to write performance objectives. In almost all instances, you will be able to find the correct answers and/or example responses for these activities at the end of this appendix. Therefore, you can undertake these activities at your own pace and at a time when you can give them your fullest attention.

Performance Terms

Unless one can measure whether a student has met an objective it is meaningless. This speaks poorly of the old standby terms such as to know, to appreciate, and to understand. We may wish to get a student to appreciate something but it is virtually impossible to measure an objective like the following one:

> One of the objectives of this unit is to help children learn how to appreciate the native wildflowers of the Midwest.

Instead, the behaviorally stated objective deals with some observable or measurable action. It describes what the student should be able to do as a consequence of an educational experience. The objective uses performance term terms. Some performance terms follow:

construct	select	analyze
compare	describe	evaluate
classify	predict	state
compute	hypothesize	test
write	experiment	design

The following examples indicate how some of these performance terms (and others) can be used behaviorally. Identify, in writing, the performance terms used in the examples below (make sure you also identify those which are inferred as well as overt):

1. Given a multiple choice test item, the student will select the response that correctly defines the term mineral. (What is/are the performance term(s) in No. 1)?_____

_____

2. The student will be able to write a hypothesis that can be tested experimentally. Performance term(s)?_____

_____

3. The student will write a design of an experiment to test the hypothesis. Performance term(s)?_____

_____

4. Upon completing the unit, the student will be able to correctly classify twenty different line drawings of insects into groups according to insect orders. Performance term(s)?_____

_____

5. The student will show his appreciation for the need to conserve water by inspecting his home and repairing all leaky faucets found there. Performance term(s)?_____

_____

6. While comparing four specimens of reptiles the student will be able to orally state one way in which they are all similar and one way in which each differs from the others. Performance term(s)?_____

_____

(Note: Correct responses can be found at the end of this appendix.)

Are They Behaviorally Stated?

Below you will find listed six separate objectives. In the blank in front of the objective write "yes" if the objective is written in behavioral terms and "no" if it is not.

____1. The student will be able to classify twelve geometric shapes into three separate groups by placing them in three piles, each of which contains closely related kinds.

____2. The student will orally state an accurate definition of work.

____3. The student will perceive the relationship between work and energy.

____4. The student will develop an appreciation of natural resources and form an accurate concept about how he can participate in environmental education.

____5. The student will prepare a written list that includes three examples of biotic community factors and four examples of abiotic factors.

____6. The student will demonstrate a positive attitude toward the need for recycling glass by purchasing pop only in reusable containers.

Of the six objectives stated, four are written behaviorally and two are not. You should have responded "no" to numbers three and four. The term "perceive" is not a performance term nor is "appreciate". There is no way a person can observe directly someone else's understanding and appreciation. It is true that these things can be measured, but not directly.

How might you revise numbers three and four so that the desired outcomes can be observed and, therefore, evaluated? Rewrite these below:

Revision:

Revision:

There is no one way to measure either desired outcome. However, regardless of how the evaluation is done, it must be consistent with the knowledge, skill, or attitude desired. If you want to see examples of the revisions, please refer to the end of this appendix.

Applying What You Have Learned

In the following four problem situations you are asked to write certain instructional objectives in behavioral terms. In each instance your objectives are to clearly reflect the appropriate parameters for an objective. Similarly, the objective must correctly reflect the problem. It must be consistent with the operation(s) demanded of the students for whom you are writing the objective. Please be accurate in all dimensions.

PROBLEM I: Your second graders have been involved off and on through autumn with a unit on seasons. They started the first day of fall and ended the first day of winter. They kept a weekly diary of environmental changes as they observed them. One activity was to measure the length of a post's shadow every Monday at exactly 10:30 a.m. (Standard Time).

On completion of the unit you want your students to know (among other things) that their shadows will be longer at a given time in Novemer than they were on September 22. Also, you want them to know that, as fall progresses toward winter, North America is receiving less light energy from the sun and, as a result, it gets colder from September 22 throughout the fall season.

Below, write instructional objectives that will measure these learnings.

PROBLEM II: Your intermediate students are just beginning a unit on energy exchanges in biology. The book they use makes a big point of the fact that almost all food energy in the biological world comes directly or indirectly from organisms that contain chlorophyll and carry on photosynthesis. Also, photosynthesis is the process whereby green plants manufacture carbohydrates (sugars and starches) by chemically combining carbon dioxide (CO_2) and water (H_2O) in the presence of chlorophyll and light energy (usually sunlight).

You want your students "to know" three things: (1) what photosynthesis is; (2) the relationship between carbon dioxide, water and carbohydrates in the green plant; (3) the relationship between photosynthesis and food energy in the biological world. Write three instructional objectives in behavioral terms that measure the student's knowledge in each of these dimensions. Do this below:

PROBLEM III: You are involved in a unit on soil conservation with your fourth grade students. You have discussed Midwestern soil conservation problems. You have shown several good films that illustrate soil conservation problems and methods of attacking these problems. Many of these problems and conservation strategies are similar to those observable in the Midwest. Also, you ask the local soil conservationist to come in and talk to the students about these things. He also agrees to lead a field trip to area farms where numerous problems and conservation techniques can be observed.

Write an instructional objective that would allow you to assess whether your students can apply what they have learned in the classroom to what they see in the field. They must exhibit knowledge about <u>both</u> problems and conservation strategies. Do this below:

PROBLEM IV: You are teaching upper grade students about food chains and food webs in the environment. You illustrate the food chain concept by using an example from the forest community. The example begins with the food producing green plant (an oak) that produces acorns. Some of these acorns are eaten by chipmunks that live on the forest floor. The chipmunk is a first order consumer in this instance. The chipmunk, in turn, is eaten by a coyote who acts as a second order consumer.

Following this simple food chain example you proceed to tell the students that food webs are more complex. The acorn, for example, is not always eaten by the chipmunk. It can be eaten by a squirrel. It could be eaten by a number of different insects. Any of these animals could be preyed upon by others. The same is true for the chipmunk. It could be preyed upon by a fox, a red-tailed hawk, or a great-horned owl. It might also have a couple of worm parasites living in its intestine. These are all factors that should be considered in a food web involving numerous organisms.

You want to find out whether your students understand the <u>difference</u> between a food chain and a food web. Similarly, you also want <u>evidence</u> to indicate that they can reconstruct a simple food chain and a fairly <u>simple</u> food web. Write <u>one</u> instructional objective that will measure <u>both</u> of these desires. Do this <u>below</u>:

Correct Responses for Appendix C.

Performance Terms:

1. select, (define)*; 2. write, (hypothesize)*; 3. write (design)*; 4. classify; 5. inspect, repair; 6. compare, state. (*performance terms that are inferred in the individual statements, e.g., in No. 2, the student is asked to write a hypothesis so the inferred task is hypothesizing. The student is not asked to experiment in No. 2 so experimentation would not be a performance term in No. 2.)

Are They Behaviorally Stated? (Example Responses)

3. The student will prepare a written statement, not to exceed 50 words, which describes the relationship between work and energy.

4. The student will present a 10 minute oral report which partially explains the importance of soil, water, forest, and wildlife resources. Subsequently, he will state one way in which he can successfully participate in the conservation of at least three of these resources.

Applying What You Have Learned: (Example Responses)

1. Asked whether his shadow is longer at 2:00 P.M. on September 22 or on November 22, the student will respond with the correct answer.

Asked if his home town or school gets more light energy from the sun in October or November, the student will respond with the correct answer. Subsequently, when asked if it gets colder or warmer from September to December, he will respond correctly.

2. Following the lesson on energy exchanges in the biosphere, the student will be able to . . . (a) . . . select the correct response in a multiple choice test item which explains that photosynthesis is the process whereby green plants manufacture food. (b) . . . orally state the names of the two compounds which are chemically combined in the presence of chlorophyll and light energy when carbohydrates are being produced by a green plant. (c) . . . write a sentence of no more than 20 words explaining the relationship between photosynthesis and food energy in the biosphere.

3. Following the unit on soil conservation the student will, given a sheet of paper on which five soil conservation problems are listed and five control measures listed, be able to orally state the locations where three of each of these were observed during the field trip.

4. Following the instruction on food chains and food webs the student will be able to construct a simple diagram of a food chain (minimum of three steps) and a diagram of a food web (showing relationships of at least three organisms in a food web), label each organism as to whether it's a producer, first-order consumer, etc., and state in writing which diagram is the food chain and which is the food web.

APPENDIX D

Preparing For Instruction: A Synthesizing Activity

Reread Part II of your worktext, "Why Teach Science to Children". Carefully consider all of the components/goals of "scientific literacy" as described in this section. Remember that scientific literacy is a major goal for a sound general education for boys and girls. Also reread Part IX of your worktext, "Preparing Instructional Materials". It might also be helpful to read the materials found in Appendix A, More on Concepts - An Assignment.

An Introduction To This Assignment

You are being asked - as a future teacher - to carefully select some content component of science and think it through both educationally and instructionally.

As a consequence of this thoughtful meditation, you will prepare a paper which communicates your decisions concerning certain elements related to that content component.

The elements spoken of in the former paragraph will consist of:

1. A statement of the content component.
2. Grade level(s) under consideration.
3. A rationale for that content component having general education significance for boys and girls.
4. One or more specific performance objectives which you would teach for with respect to that content component.
5. A brief description of how you would teach for the objective(s) listed in No. 4 above.
6. A sound strategy for using this content to integrate the teaching of language arts, social studies and/or math. This step, of course, may temper your content and methods selection.

The paper itself should lay out the above elements in precisely the same order as you read them. They should similarly be numbered as observed above. The paper need not be a long one. In fact, it can't be long because there are word limitations on your presentation. Remember that one typed page is equivalent to 250 words. The paper is due on the date announced by your instructor. It would be preferable if the assignment was typed. If not, be sure your handwriting is exceptionally neat and legible.

How will the paper be graded? The paper will be evaluated on the basis of whether you have chosen content with general education significance (your rationale for this significance), grade level appropriateness, clarity and educational significance of your objective(s), adequacy of your plan for teaching this content, and potential effectiveness of your plan for integrating this content with other curricular areas. Of course, all parts of the assignment must be consistent with (related to) all other parts.

Complete the assignment! Further information on the elements follow:

1. CONTENT COMPONENT (One or two sentence limit here)

This requires a statement of the content you intend to teach. The content component can be related to science concepts (content) or the nature of science, or science and technology or science-related social issues or science processes or scientific attitudes, or science career awareness. You will find numerous examples in your worktext readings, from your textbook assignment or from elementary science textbooks. Be very CAREFUL NOT to simply select something from these sources unless you can make a good case for it. An example might be: Science and technology differ in terms of their purposes. Science produces knowledge while technology makes applications of that technology.

2. GRADE LEVEL(S)

Identify the optimum grade level at which the content component can be taught. Be careful in your selection. This has implications for objectives, teaching strategies, and a host of other variables. If it is necessary to explain your grade level choice, here is the place to accomplish that.

3. RATIONALE (150 word limit)

Make certain you state your case for this content having general education significance (important for scientific literacy). Be specific as to why children need to learn this.

4. PERFORMANCE OBJECTIVE(S). IMPORTANT: If you are making certain assumptions regarding prerequisite knowledge that students already have, please state them prior to stating your objectives. Also, your objectives should be limited to no more than five.

Make certain that the objectives are:

a) well written using performance terms.
b) appropriate for the content and the instructional strategy.
c) reflect educationally significant outcomes - watch your taxonomic levels; aim for higher levels whenever possible.
d) placed in a logical sequence.

5. TEACHING STRATEGY (250 word limit)

Plan and record . . .

a) what you are going to do.
b) how you are going to do it.
c) the sequence of what you are going to do.

NOTE: Be sure that the strategies correlate with the objectives. Also, although you do not have enough space to go into immense detail here, do communicate clearly what educational activities the children will experience.

6. INTEGRATING THE CONTENT (250 word limit)

How will you use this content to work toward desirable goals/objectives in language arts, social studies, and/or math. Identify the content areas you are integrating and be specific regarding your integration plans. Said in another way, what learnings in any of these content areas will be achieved and how will you achieve them in an interdisciplinary fashion?

THAT'S IT!

APPENDIX E

Resources and References for Elementary School Science Teachers

Several of the problems of the elementary school science teacher are those of "Where do I look for . . ?" or "How do I do this . . .?" or better yet, "What can I do, activity-wise to teach science well?". The following listings should provide you with information sources as at least a beginning answer to the questions stated above. For a more complete listing check the National Science Teachers Association publication, Science and Children, Volume 21, Number 4, January 1984.

TEXTBOOK/PROGRAM PUBLISHERS

Name	Text/Program
Addison-Wesley Publishing Co. 2725 Sand Hill Rd. Menlo Park, CA 94025 (415) 854-0300	Addison-Wesley Science (K-6)
Coronado Publishers, Inc. 1250 Sixth Ave. San Diego, CA 92101 (619) 699-6280	New Elementary Science (K-8)
Delta Education, Inc. P. O. Box M Nashua, NH 03061-6012 1-800-258-1302	SCIIS (Science Curriculum Improbement Study) (K-6) SAPA-II (Science - A Process Approach) (K-6) Elementary Science Study (ESS) (K-9)
Ginn and Company 191 Spring Street Lexington, MA 02173 (617) 861-1670	Elementary Science (K-6)
Harcourt Brace Jovanovich 757 Third Ave. New York, NY 10017 (212) 888-4444	Concepts in Science (K-9)
D. C. Heath and Co. 125 Spring Street Lexington, MA 02173 (617) 862-6650	Heath Science (K-6)

Holt, Rinehart and Winston CBS, Inc., 383 Madison Ave. New York, NY 10017 (212) 872-2000	Holt Elementary Science (K-6)
Houghton Mifflin Co. One Beacon Street Boston, MA 02108 (617) 725-5000	Houghton Mifflin Science (1-6)
Laidlaw Brothers Thatcher & Madison River Forest, IL 60305 (312) 366-5320	The New Exploring Science Program (K-6)
McGraw-Hill Book Co. Webster Division 1221 Avenue of the Americas New York, NY 10020 (212) 997-4585	Gateways to Science (K-6) Elementary Science Study (ESS) (K-8)
Charles E. Merrill Pub. Co. P. O. Box 508 1300 Alum Creek Dr. Columbus, OH 43216 (614) 890-2111	Accent on Science (K-6)
National Science Programs, Inc. 17 W. Wilson St. Batavia, IL 60510 (312) 879-6901	BSCS Human Sciences Program (K-12)
Scott, Foresman and Co. 1900 E. Lake Ave. Glenview, IL 60025 (312) 729-3000	Scott, Foresman Science (K-6)
Silver Burdett Co. 250 James St. Morristown, NJ 07961 (201) 285-7700	Silver Burdett Science (K-6)

MEDIA PRODUCERS

The term "Media Producer" denotes a wide variety of material types, e.g., films, filmstrips, filmloops, slides charts/maps, games, ditto masters, and computer software. Therefore, the following addresses comprise a variety of sources for a variety of materials. The authors of your worktext have chosen to list only those producers that hold the greatest promise for the elementary teacher. Some of the suppliers are specialists in a particular field, e.g., Projected Learning Programs furnished mostly slides and filmstrips and not other types of materials while others produce a variety of materials.

Name	Materials in Stock
ABC Science Co. 3907 Belle Rive Ter. P. O. Box 15273 Alexandria, VA 22309	Pictures/Cards Overhead Transparencies Slides
Apple Computer, Inc. 20525 Mariani Ave. Cupertino, CA 95014	Computer Software
AstroMedia Corp. 625 E. St. Paul Ave. P. O. Box 97288 Milwaukee, WI 53202	Slides Pictures/Cards
Astronomical Society of the Pacific 1290 24th Ave. San Francisco, CA 94122	Slides Charts/Maps Pictures/Cards
Carolina Biological Supply Co. 2700 York Rd. Burlington, NC 27215	Filmstrips Slides Videotapes/Cassettes Computer Software
Damon/Instructional System 80 Wilson Way Westwood, MA 02090	Filmstrips Slides Videotapes/Cassettes
Delta Education, Inc. P. O. Box M Nashua, NH 03061-6012	Pictures/Cards Games Ditto Masters
Encyclopaedia Britannica Educational Corp. 425 N. Michigan Ave. Chicago, IL 60611	Films Filmstrips Slides Overhead Transparencies Pictures/Cards Computer Software

Hansen Planetarium Publications 15 So. State Street Salt Lake City, UT 84111	Slides Overhead Transparencies Charts/Maps Pictures/Cards
Ideal School Supply Co. 11000 S. Laver Ave. Oak Lawn, IL 60453	Charts/Maps Games Ditto Masters
International Film Bureau, Inc. 332 S. Michigan Ave. Chicago, IL 60604	Films Videotapes/Cassettes
McGraw-Hill Webster Division 1221 Avenue of the Americas New York, NY 10020	Filmstrips Ditto Masters Computer Software
MMI Space Science Corp. 2303 N. Charles St. P. O. Box 19907 Baltimore, MD 21211	Films and Filmstrips Filmloops Slides Overhead Transparencies Pictures/Cards Computer Software
Nasco 901 Janesville Ave. Fort Atkinson, WI 53538	All Types
National Geographic Society 17th and M Sts., N.W. Washington, D. C. 20007	Films and Filmstrips Videotapes/Cassettes
National Science Programs, Inc. P. O. Box 41 Batavia, IL 60510	Mass Types of Media
Phoenix/BFA Films and Video, Inc. 468 Park Ave. South New York, NY 10016	Films and Filmstrips Videotapes/Cassettes Computer Software
Projected Learning Programs, Inc. P. O. Box 2002 Chico, CA 95927	Filmstrips Slides
Sargent-Welch Scientific Co. 7300 N. Linder Skokie, IL 60077	Mass Types of Media
Science and Mankind, Inc. Communications Park Box 2000 Mount Kisco, NY 10549	Films and Filmstrips Slides Videotapes/Cassettes

Science Kit and Boreal Laboratories
777 E. Park Dr.
Tonawanda, NY 14150

Mass Types of Media

Scott Resources/ESNR Division
P. O. Box 2121
401 Hickory St.
Fort Collins, CO 80522

Mass Types of Media

Society for Visual Education
1345 Diversey Parkway
Chicago, IL 60614

Filmstrips
Pictures/Cards
Computer Software

SCIENCE EQUIPMENT/SUPPLIES

The following suppliers of science equipment and supplies are those who handle a wide variety of materials for the science classroom/laboratory. Usually, it is possible to obtain catalogs from these sources, particularly if requested on school letterhead stationery.

ABC Science Company
3907 Belle Rive Ter.
P. O. Box 15273
Alexandria, VA 22309

Carolina Biological Supply Co.
2700 York Rd.
Burlington, NC 27215

Central Scientific Co. (CENCO)
11222 Melrose Ave.
Franklin Park, IL 60131

Connecticut Valley Biological
Supply Co., Inc.
82 Valley Rd.
Southampton, MA 01073

Damon/Instructional Systems
80 Wilson Way
Westwood, Ma 02090

Delta Education, Inc.
P. O. Box M
Nashua, NH 03016-6012

Fisher Scientific Co.
4901 W. LeMoyne St.
Chicago, IL 60651

Frey Scientific Co.
905 Hickory Lane
Mansfield, OH 44905

Hach Company
P. O. Box 389
Loveland, OH 80537

Ideal School Supply Company
11000 S. Lawrence Avenue
Oak Lawn, IL 60453

Nasco
901 Janesville Ave.
Fort Atkinson, WI 53538

Sargent-Welch Scientific Co.
7300 N. Linder
Skokie, IL 60077

Schoolmasters Science
745 State Circle
P. O. Box 1941
Ann Arbor, MI 48106

Science Kit and Boreal Labs.
777 E. Park Dr.
Tonawanda, NY 14150

Ward's Natural Science Establishment, Inc.
5100 West Henrietta Rd.
P. O. Box 92912
Rochester, NY 14692

SOURCES OF INFORMATION REGARDING THE ENVIRONMENT AND ENVIRONMENTAL EDUCATION

Organizations:

American Forestry Association
919 Seventeenth St. N. W.
Washington, D. C. 20006

American Petroleum Institute
1271 Avenue of the Americas
New York, N. Y. 10020

Animal Welfare Institute
P. O. Box 3656
Washington, D. C. 20007

Bureau of Land Management
U. S. Department of the Interior
Washington, D. C. 20050

Center for Environmental Education
Suite 307
2011 M Street, N. W.
Washington, D. C. 20037

Common Cause
2100 M Street, N. W.
Washington, D. C. 20037

Conservation Foundation
1250 Connecticut Ave., N. W.
Washington, D. C. 20036

Council on Environmental Quality
722 Jackson Place, N. W.
Washington, D. C. 20006

Defenders of Wildlife
2000 N. Street, N. W.
Washington, D. C. 20036

Division of Air Pollution
Public Health Service
U. S. Dept. of Health, Education and Welfare
5600 Fishers Lane
Rockville, MD 20852

Environmental Action, Inc.
Room 731
1346 Connecticut Avenue, N. W.
Washington, D. C. 20036

Environmental Defense Fund
1525 18th Street, N. W.
Washington, D. C. 20036

Environmental Protection Agency
401 M Street, S. W.
Washington, D. C. 20460

Federal Water Pollution Control Administration
Office of Public Information
Washington, D. C. 20242

Forest Service
U. S. Dept. of Agriculture
Washington, D. C. 20242

Friends of the Earth
620 C. Street, S. E.
Washington, D. C. 20003

Garden Clubs of America
Conservation Committee
598 Madison Avenue
New York, N. Y. 10022

Illinois Natural History Survey
Natural Resources Building
Urbana, Illinois 61801

Ill. State Dept. of Conservation
Springfield, Illinois 62706

Illinois State Geological Survey
Natural Resources Building
Urbana, Illinois 61801

Illinois State Museum
Spring and Edwards Street
Springfield, Illinois 62106

Izaak Walton League of America
1326 Waukegan Road
Glenview, Illinois 60025

League of Conservation Voters
324 C Street, S. E.
Washington, D. C. 20003

Midwest Coal Producers Institute
Wildwood Lane
Springfield, Illinois 62700

National Air Pollution Control Administration
Federal Building
26 Federal Plaza
New York, N. Y. 10007

National Audubon Society
950 Third Avenue
New York, N. Y. 10022

National Wildlife Federation
1412 Sixteeenth St., N. W.
Washington, D. C. 20036

Natural Resources Defense Council, Inc.
917 15th Street, N. W.
Washington, D. C. 20005

The Nature Conservancy
Suite 800
1800 N. Kent St.
Arlington, VA 22209

Planned Parenthood - World Population
810 7th Avenue
New York, N. Y. 10019

Population Crisis Committee
1835 K Street, N. W.
Washington, D. C. 20006

Population Reference Bureau, Inc.
1754 North Street, N. W.
Washington, D. C. 20036

Resources for the Future, Inc.
1755 Massachusetts Ave., N. W.
Washington, D. C. 20036

Sierra Club
530 Bush Street
San Francisco, California 94108

Soil Conservation Service
U. S. Dept. of Agriculture
Washington, D. C. 20401

Superintendent of Documents
Government Printing Office
Washington, D. C. 20402

The Wilderness Society
1901 Pennsylvania Avenue
Washington, D. C. 20006

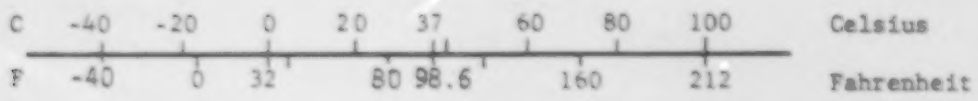
Zero Population Growth
1346 Connecticut Avenue, N. W.
Washington, D. C. 20036

APPENDIX F

Metric Measure

The universal system of measurement in science is the metric system. This appendix is provided to give you some assistance in seeing the relationships between the metric and English systems. It is highly recommended that you have your students make all measurements in the metric system rather than getting them involved in converting English system measurements into metric ones.

Temperature:



To obtain a Celsius temperature, subtract 32 from the Fahrenheit temperature. Take 5/9 of that figure. Example:

212 F
- 32
180 x 5/9 = 100 C.

To eliminate fractions, a second way is to subtract 32 from the Fahrenheit temperature and divide that figure by 1.8. The formula for this process is C = F - 32/1.8.

To obtain a Fahrenheit temperature multiply the Celsius temperature by 9/5. Add 32 to this figure. This yields Fahrenheit temperature. Example:

37 C x 9/5 = 66.6
+ 32.0
98.6 F

To eliminate fractions, another method is to multiply the Celsius temperature by 1.8 and then add 32 to that derived figure. The formula for this method is F = 1.8C + 32.

Weight (Mass):

1 ounce	=	28 grams (g)
1 pound	=	0.45 kilograms (kg)
1 ton (2000 lb.)	=	0.9 tonnes (t)

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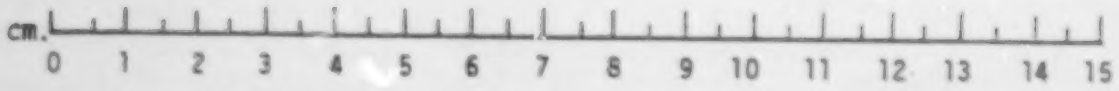
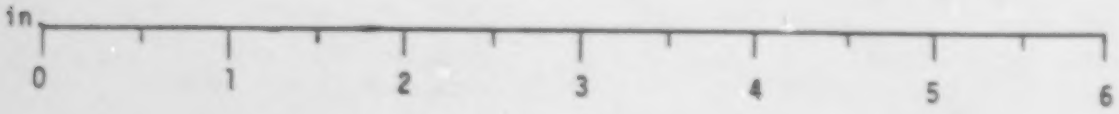
1 gram (g)	=	0.035 ounces
1 kilogram (kg)	=	2.2 pounds
1 tonne (1000 kg)	=	1.1 tons

Linear Measure:

Approximate conversions both ways . . .





1 inch	=	2.54 centimeters (cm)
1 foot	=	30 centimeters (cm)
1 yard	=	0.9 meters (m)
1 mile	=	1.6 kilometers (km)

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1 millimeter (mm)	=	0.04 inches
1 centimeter (cm)	=	.4 inches
1 meter (m)	=	3.3 feet
1 meter (m)	=	1.1 yards
1 kilometer (km)	=	0.6 miles

Volume:

1 milliliter (m)	=	0.03 fluid ounces
1 liter (l)	=	2.1 pints
1 liter (l)	=	1.06 quarts
1 cubic meter (m^3)	=	1.3 cubic yards

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1 teaspoon	=	5.0 milliliters (ml)
1 tablespoon	=	15.0 milliliters (ml)
1 ounce	=	30.0 milliliters (ml)
1 pint	=	0.47 liters (l)
1 cubic yard	=	0.76 cubic meters (m^3)

APPENDIX G

Textbook Appraisal

Your Name_____ Date_____

Publisher_____ Pub. Date_____

Author(s)_____ Grade Level Chosen_____

I. Certain science content is represented in particular chapters or units in every text, e.g., botany, geology, earth science. First, in the left hand column, list the unit/chapter titles presented in the textbook in the order in which they appear in the text and number them. Second, place the chapter number in front of each content area (right hand column) which is represented in that chapter. Several content areas might be associated with a particular chapter.

Chapter/Unit Titles	Content
_____	___ Chemistry
_____	___ Physics
_____	___ Earth Science, Astronomy
_____	___ Earth Science, Atmosphere/Weather
_____	___ Earth Science, Oceanography
_____	___ Earth Science, Geology
_____	___ General Botany (Plants)
_____	___ General Zoology (Animals)
_____	___ Anatomy or Physiology (NOT Health)
_____	___ Health
_____	___ Ecology
_____	___ Science-Related Societal Issues
_____	___ The Nature of Science/The Scientist
_____	___ Science/Technology Career Awareness
_____	___ Other_____
_____	___ Other_____
_____	___ Other_____

II. Are content areas covered that teach important conceptual knowledge that students cannot learn by first-hand experiences with objects and events in the environment, e.g., the solar system, space travel, oceanography, biogeography?

Yes___ No___. What is the evidence?

III. NOTE: Be sure you refer to the entire series in responding to this question. Is the text a health/science fusion, i.e., does it cover mental and/or physical health as a basic part of science? And, in particular, does the text assist children in forming and maintaining good health habits? (Please do NOT consider the study of anatomy and physiology per se as evidence of health instruction.)

Yes___ No___. What is the evidence?

IV. Questions are asked of students in any science text. They are found interspersed within chapters or at a special section at the end of the chapter or both. Please study the manner in which the authors have stated these questions. Respond to the following:

A. To what extent do the authors ask the children to respond to questions measuring only low level factual information?

X	X	X	X	X
To A Minimal Extent		To A Moderate Extent		To A Great Extent

Why did you respond in this manner? (Evidence)

B. To what extent do the authors ask the children to respond to questions measuring the acquisition of concepts or the children's ability to apply concepts in new and unique situations?

X	X	X	X	X
To A Minimal Extent		To A Moderate Extent		To A Great Extent

Why did you respond in this manner? (Evidence)

V. Most texts claim that they are activity (experientially) oriented. These activities, oftentimes called experiments or investigations, are found interspersed within chapters or units or at a special section at the end of the chapter or both. Carefully examine the manner in which the authors have developed these activities. Then respond to the following:

A. To what extent are the activities structured to have the child inductively form a concept rather than deductively demonstrate an already pre-stated concept?

X	X	X	X	X
To A Minimal Extent		To A Moderate Extent		To A Great Extent

B. To what extent are activities developed so that there is an opportunity for open-ended, independent investigation rather than following a prescribed sequence of events which lead to a predetermined answer?

X	X	X	X	X
To A Minimal Extent		To A Moderate Extent		To A Great Extent

C. Briefly defend the responses you made to A and B above, i.e., why did you answer as you did? (Evidence)

VI. Is there any evidence in the student text to indicate that students gain a concept of what science is? This could be accomplished with a direct definition, discussion or repeated reference to science. Although a child might gain this concept inductively, by experiencing science in a realistic manner, your instructor must perceive an adequate explanation if you use this perspective in your reasoning.

Yes___ No___. Why did you respond in this manner?

VII. To what extent do the text's authors present information dealing directly with science-related societal issues? Examples of such issues would be genetic engineering, human population growth, endangered species, deforestation of tropical rain forests, etc.

X	X	X	X	X
To A Minimal Extent		To A Moderate Extent		To A Great Extent

Why did you respond in this manner? (Evidence)

VIII. To what extent do students get training in order to develop specific science processes, e.g., hypothesizing, comparing, classifying, predicting, and experimenting?

X	X	X	X	X
To A Minimal Extent		To A Moderate Extent		To A Great Extent

Why did you respond in this manner? (Evidence)

IX. To what extent are children evaluated in a manner that is consistent with stated objectives and/or textual content?

X	X	X	X	X
To A Minimal Extent		To A Moderate Extent		To A Great Extent

Why did you respond in this manner? (Evidence)

X. Most textbook publishers make a point of noting that a particular text develops important concepts. Choose any one specific concept from anywhere in the text, state the concept below, and continue with this part of the assignment as directed below: (An Example Concept: Energy is exchanged in the environment through food chains beginning with the food producing green plant.)

Write the chosen concept in this space:

Page ____:

A. What printed information and/or illustrations are found in the text which would help the child develop this particular concept?

B. What science experiences (laboratory or otherwise) do students get with regard to this particular concept? In other words, what do students DO to help them learn this concept?

C. What suggestions are there in the Teacher's Edition for the development of this concept?

D. Do A, B, and C above provide enough information and experiences to permit the thorough development of this concept? Defend your answer! Think it through carefully!

Yes___ No___. Why did you respond in this manner?

XI. Are various kinds of illustrations used to good advantage in this series? Consider how line drawings, full color art work, and full color photographs are used to supplement the learning of specific types of content/concepts. Comment using specific examples.

Yes___ No___. Comments:

XII. Please inspect the Teacher's Guide for the text you are analyzing. Respond to the following:

Does the Teacher's Guide . . .

A. . . .clearly present instructional objectives for each unit/chapter? Yes___ No___.

B. . . .provide the teacher with adequate supplementary information on the science content being presented to the students in each unit/chapter? Yes___ No___.

C. . . .provide the teacher with lists of resources he/she may go to for further information on the science content being presented in each unit/chapter? Yes___ No___.

D. . . .communicate teaching methodologies which would maximize teacher effectiveness in teaching the units/chapters? Yes___ No___.

E. . . .provide the teacher with descriptions of supplementary materials (e.g., films, filmstrips, trade books) which could be profitably used with students? Yes___ No___.

F. . . .provide suggestions to the teacher for integrating science content with other content areas in the curriculum (e.g., reading, social studies, composition, mathematics)? Yes___ No___.

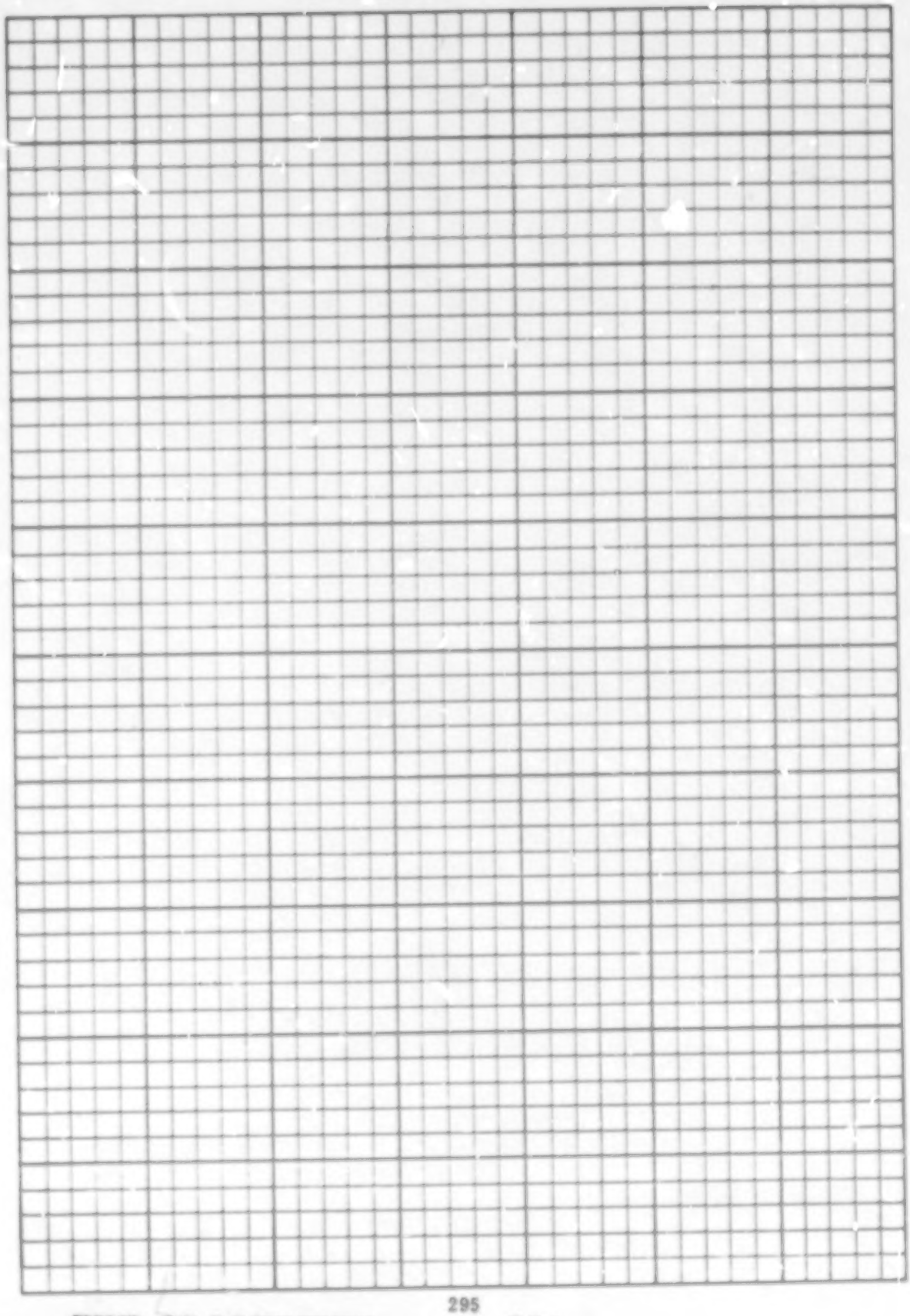
G. . . .reflect an organization which would facilitate the teaching of the unit/chapter (i.e., make the teacher's task easier and/or more efficient)? Yes___ No___.

XIII. Please assume that, for one reason or another, you had to use this textbook series in your own classroom as the basic science program. With this thought in mind, please do the following:

A. List what you perceive as this text's general education (scientific literacy) strengths, if any.

B. List what you perceive as this text's general education (scientific literac
weaknesses, if any?

C. Prepare a detailed explanation of how you would use this series, modify it, or supplement it in order to gain the best possible science program for your students? In other words, how would you use this series to provide for scientific literacy on the parts of your students? Please be very specific in your presentation. You may add a sheet to this assignment for your response if necessary.



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